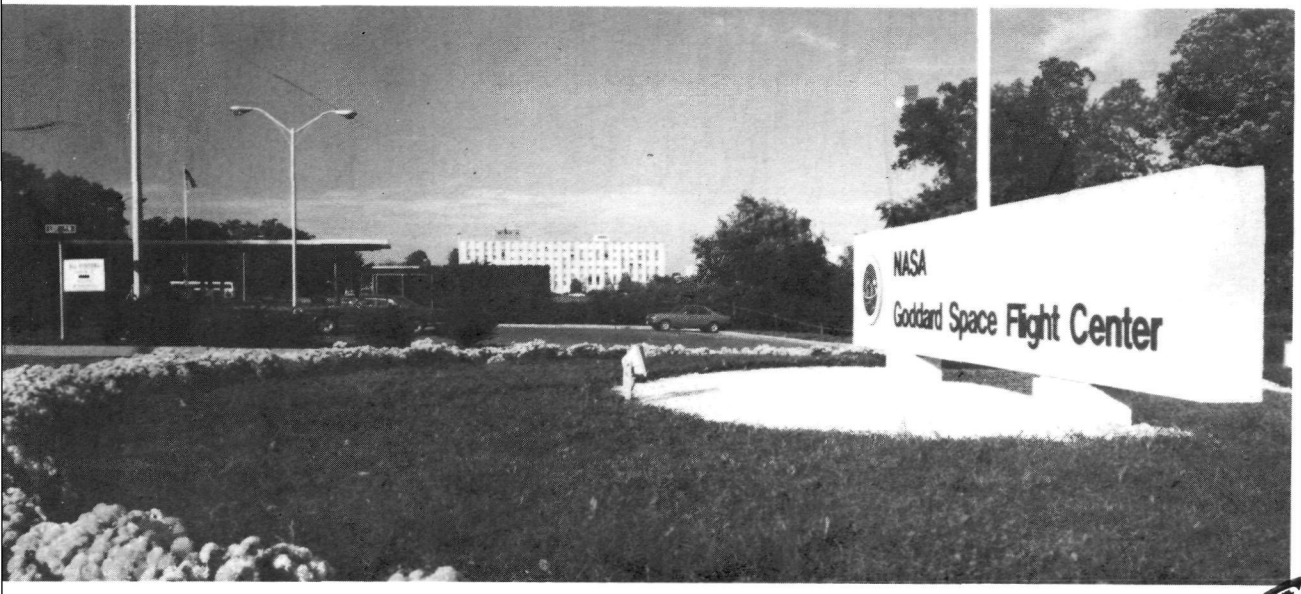
# Research and Technology 81




## Fiscal Year 1981 Annual Report



NASA
National Aeronautics and Space Administration

**Goddard Space Flight Center**
Greenbelt, Maryland

# Table of Contents

# I Introduction and Summary

During Fiscal Year 1981, the Goddard Space Flight Center continued to contribute to the goals and objectives of the Nation's space program by undertaking a wide variety of basic and applied research, technology developments, data analyses, applications investigations and flight projects. The highlights of these research and technology efforts are described in the following paragraphs.

In the Space Sciences Program, a number of important scientific discoveries were made through continued flight missions and data analysis. Some of the significant achievements during the year include:

- The most successful space astronomical observatory in NASA's history, the International Ultraviolet Explorer (IUE), completed its fourth year of operation.

- IUE has led to a major advancement in the evolution of space astronomy as a discipline by significantly influencing the research of hundreds of astronomers around the world.

- The first ultraviolet spectra of planetary nebulae (a small gas cloud) in galaxies beyond the Milky Way were obtained with the IUE.

- The Solar Maximum Mission Observatory and ground-based observatories yielded a detailed and exciting picture of what happens at the moment a solar flare is born.

- The IUE, with exposures up to seven hours long, was used to record the first ultraviolet spectra of individual stars in M33, a galaxy 2.4 million light years distant.

- Voyager radio astronomy observations of Saturn yielded a fascinating view of that planet's radio emissions. The intense, kilometer wavelength noise bursts were first discovered by Voyager in early 1980, and by utilizing data from the two Saturn encounters Goddard scientists have been able to locate the source of the radiation in two relatively small regions on the planet.

- Magnetic field measurements obtained by a magnetometer aboard Voyagers 1 and 2 at Saturn revealed a giant ring of electrical currents that flow around the planet.

- Investigation of physical processes in the terrestrial magnetosphere and nearby solar wind continued using measurements from instruments aboard the Interplanetary Monitoring Probe 8, International Sun-Earth Explorer 1 and 3 and Scatha spacecraft, and a whole new dimension to our study of coupling between the Earth's magnetosphere and upper atmosphere was opened by the successful launching of the Dynamics Explorer satellites.

- Analysis of the interplantary medium in regions far from Earth was made possible by measurements collected by Goddard instruments aboard Helios and Voyager.

- Two Voyager spacecraft encounters with Saturn lead to a number of new discoveries concerning the properties of plasmas in Saturn's space environment.

In the Space and Terrestrial Applications Program area, a number of significant accomplishments are reported in the areas of Atmospheric Science and Applications, Upper Atmospheric Research, Earth Science and Applications, Information Extraction and Sensor Development. The accomplishments in each area included:

- The first phase of a Pilot Climate Data Base Management System was completed in 1981 providing important climate data to NASA and the research community at large.

- A satellite data impact study recently completed indicated that proper use of satellite data improved by a factor of two the number of forecasts that remain skillful after five days.

- Temperature soundings were obtained for the first time from our geosynchronous weather spacecraft important for weather research.

- Stereo mapping from two geosynchronous satellites revealed unprecedented features of tornados, storms and hurricanes making it possible to determine cloud top growth rate and other important parameters for severe storm research.

- Sea surface temperature determination using microwave radiometers demonstrated that accuracies in the order of $1^{o}K$ can be obtained.

- New LIDAR techniques using continuous wave lasers have demonstrated that atmospheric levels can be determined to about 1 1/2 mb and temperature accurate to about $1/2^{o}C$.

- Molecular line spectra have been measured for CO, CH4 and OCS with a resolution of one part in $10^5$ for the first time in a wavelength region of 2 to 10 m.

- Aircraft experiments have demonstrated the feasibility of measuring directional ocean wave spectra from space using a rather simple short pulse radar.

- It has been found that solar radiation, both in the ultraviolet and the total radiation as measured by orbiting spacecraft (Atmospheric Explorer, Nimbus F, Solar maximum) is a function of the passage of regions of solar activities on the face of the sun. These in turn may be responsible for climate changes known to occur in cycles of tens of years.

- Using a three dimensional theoretical model relating the density structure to the dynamic properties of the Venus atmosphere it has been shown that the upper atmosphere must rotate about 30 times faster than the planet itself. This is considered a central problem of atmospheric dynamics and is important for the study of our own atmosphere.

- Spacecraft data from the Solar Backscatter Ultraviolet Experiments indicate an ozone decrease centered around an altitude of about 40 km where destruction of ozone due to release of chlorofluorocarbons has been predicted to be a maximum.

- The position of jet streams, atmospheric fronts and avoidance of high ozone areas for aircraft were studied. A real-time test was successfully made in cooperation with Northwest Airlines which used these data for actual flight planning.

- Comparison of model calculations of carbon monoxide with available data concerning its Latitudinal variation shows the effects of industrial sources in the mid latitude Northern Hemisphere but also indicates a substantial tropical source yet unidentified.

- A new ocean geoid essential for global ocean current studies has been developed with a r.m.s accuracy of about 1 meter averaged over an 100X100km ocean area. Distances of up to 4000km were determined to about 4 cm using both laser and very long baseline interforo metric techniques (independently) an important result for the studies of fault and plate motion.

- The first ever global component map of the Earth's magnetic field was published and accepted by the International Association of Geomagnetism and Aeronomy which constitutes a significant contribution to the study and understanding of our planet Earth.

- A snowmelt runoff model has been tested successfully to an accuracy of a few percent on river basins as large as $4000km^2$ using Landsat snow cover data. Snow depth determinations using space borne microwave radiometers have successfully been made of large uniform regions (Canadian High Plains, US Northern Great Plains and Central Russia).

- Water stress has been determined for the first time using laser induced fluorescence.

The Domestic Information Display System developed at the request of the Executive Office of the President was delivered during the end of last year providing operational support of policy and analysis planning for the Government.

A conceptual design of a Transportable Application Executive System was recently completed. This system provides a user interface and parameter processing function important for swift and economical data management so essential for future space exploration data handling.

A contour map of chlorophyll - a distribution near the Nantucket Shoals has been produced using laser fluorescence techniques. This was the first time that a warm water ring has been mapped this way, demonstrating a new technology for ocean research.

An oil film thickness determination was made using laser techniques useful for pollution studies and monitoring.

Using aircraft instrumentation, during actual flight tests, it was demonstrated that nitric oxide levels in clean areas could be measured, important for the development and testing of atmospheric chemistry models.

An Ocean Color Experiment on Shuttle II was successfully performed demonstrating that bioproductivity, important for fishing, can be determined from space.

The Flight Projects and Mission efinition Study Program continues work in developing spacecraft for ar-term missions and defining advanced mission concepts, payloads and requirements for future missions. The major flight missions on which Goddard engineers continued to work included:

- Completion of the first scientific applications and technology for the Space Transportation System (STS-3).
- Selected four scientific instruments for the Gamma-Ray Observatory mission.
- Successful launch and operation of the first and second Dynamics Explorer satellites (DE 1-2).
- The first of two production Multimission Modular Spacecraft was delivered to the Landsat-D Mission Integration Contractor.
- Continued studies and design efforts on future flight missions such as the Earth Radiation Budget, Cosmic Background Explorer and Gravsat/Magsat A.

The Space Tracking and Data Systems Program concentrated on communication link, data transport, support services and precision tracking activities. Some of the significant project efforts in this program area included:

- Hardware models of the performance of the TDRSS RF communications links in the presence of interference were evaluated.
- A digital voice capability for use with the Shuttle was integrated into the GSTDN.
- A new ultra-precision hydrogen maser clock was developed which keeps time to better than 1 billionth of a second per day.
- A network of laser tracking stations successfully tracked three satellites with ranging accuracy on the order of 2 to 3 centimeters.
- New high speed data transfer equipment has been developed that is capable of transferring data at rates of thousands of megabits per second.

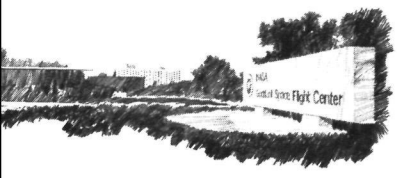
The Space Technology Program continued its efforts in developing advanced technology for application in cost-effective and reliable space systems that are of public benefit and that support national needs. Significant accomplishments were made in areas of information systems, infrared observation sensors, and power systems. The major accomplishments in this area included:

- Designs were completed for the prototype NASA End-to-End Data System.
- Models of the End-to-End Systems which allow for real-time buffer configuration and network simulation were completed.
- A pilot system of a resource allocation and event scheduler data management system was successfully demonstrated in the Multisatellite Operations Control Center (MSOCC).

Page intentionally left blank

Page intentionally left blank

# II Space Sciences



*The GSFC space sciences activities are directed toward the investigation of the Earth's space environment, the Sun, the solar system, the interplanetary medium, galactic and extragalactic phenomena, and the interrelationships of each of these. GSFC scientists continued to pursue a wide variety of research studies, data analysis efforts, instrument developments and measurement projects to increase man's understanding of the universe. Major efforts were devoted to the detailed study, analysis, and interpretation of data obtained from observations of a number of space missions.*

## ASTRONOMY AND SOLAR PHYSICS

The most successful space astronomical observatory in NASA's history, the International Ultraviolet Explorer (IUE), is completing its fourth year of operation. The success of IUE can best be demonstrated by the extremely high output of scientific papers resulting from its use. The development of the first near real-time astronomical data reduction system for both quick-look and final processed data makes possible the rapid analysis and publication of the scientific results from this satellite. IUE has led to a major advancement in the evolution of space astronomy as a discipline by significantly influencing the research of hundreds of astronomers around the world. This has resulted in the creation of an entirely new generation of "space astronomers," i.e., those hundreds of astronomers, who, prior to IUE, never considered space observatories as accessible or useful research tools. The real-time interactive control of the telescope and of the data has been a primary factor in simulating the successful use of the IUE by a large segment of the astronomical community. A number of "firsts" have been achieved with the IUE during the past year.

An international team of solar physicists continues to work in residence at the Goddard Space Flight Center on the results of the Solar Maximum Mission. This highly successful solar flare mission continues partial operation after failure in November 1980 of the attitude control system on the SMM observatory. Three of the seven instruments onboard, the Gamma-Ray Experiment, the Hard X-Ray Burst Spectrometer and the Active Cavity Radiometer Intensity Monitor (the solar constant experiment) continue to obtain high quality data. A proposal has been submitted to NASA Headquarters for repair of the SMM using the Space Transportation System. If the proposal is accepted, the SMM would be returned to full operational status late in 1983. The renewed SMM would not only pursue the objective of solar flare research, but would also add quiet Sun objectives. Among the added objectives are the exploration of coronal holes and examination of the evolution of the solar corona as the solar cycle approaches its minimum. Furthermore, continuous measurement of the total energy output of the Sun as the cycle approaches minimum would be obtained. By using the Tracking and Data Relay Spacecraft during the period of the renewed SMM, intervals of real-time solar observations using the SMM should be possible.

Progress has continued on all phases of the Ultraviolet Imaging Telescope, scheduled for the third Shuttle launch, and on the High Resolution Spectrograph, one of five instruments selected for the Space Telescope.

## SMM Provides Data for Solar Flare Models

Intensive analysis of data obtained by the Solar Maximum Mission Observatory and its colloborating ground-based observatories is beginning to yield a detailed and exciting picture of what happens at the moment a solar flare is born. Solar flares occur in small patches on the surface of the Sun known as active regions. Sun spots also appear in active regions and are evidence of intense magnetic energy welling up from below the surface of the Sun, the photosphere. Exciting new observations have been made with the SMM when a flare is ignited. These have appeared at the base of magnetic arches or loops. The relatively cool gas found here brightens rapidly and begins to move at high velocity. This occurs simultaneously with the appearance of brightenings in hard X-ray emission. The hard X-rays are taken as evidence that electrons accelerated in the magnetic arch structure are responsible for heating of cool gas at the base. So much energy is fed into the cool gas that it not only brightens immensely, but expands explosively as well to fill the entire loop structure. During this process, temperatures from 200,000$^{o}$ to 40,000,000$^{o}$F have been measured, and tens of thousands of tons of gas moving at velocities of 100 to 300 kilometers per second have been detected. Recording of the detailed sequence of events occurring at this time in a solar flare is a unique contribution of the Solar Maximum Mission.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. Arthur I. Poland
Telephone: (301) 344-8771

## IUE Looks at Individual Stars in M33

The International Ultraviolet Explorer (IUE), with exposures up to seven hours long, has been used to record the first ultraviolet spectra of individual stars in M33, a galaxy 2.4 million light years distant. These observations permit studies of the most luminous blue stars in this galaxy and provide information on the evolution of very massive stars. These stars appear to be similar to Eta Carina, a most peculiar star in our galaxy and a star that dramatically brightened in 1843. Eta Carina today is losing mass at the rate of a solar mass per 1000 years.

These observations were thought not possible until the Space Telescope. Now it appears that the IUE can begin fundamental studies of individual stars in nearby galaxies and should pave the way for major studies by the Space Telescope.

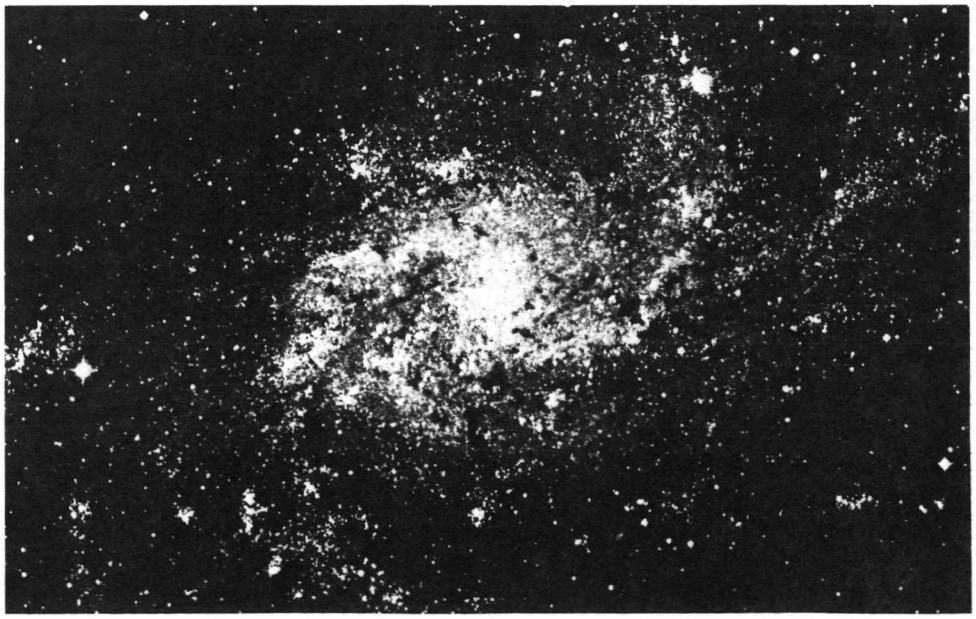
Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. Theodore R. Gull
Telephone: (301) 344-5401

## First Ultraviolet Spectroscopy of Planetary Nebulae Beyond the Milky Way

The first ultraviolet spectra of planetary nebulae in galaxies beyond the Milky Way were obtained with the International Ultraviolet Explorer (IUE). A planetary nebula is a small gas cloud in space, formed when a red giant star ejects its outer atmosphere. These nebulae interest scientists because their chemical composition provides clues to the nuclear reactions and gas motions that took place within their parent stars prior to the ejection of the nebulae.

An ordinary main sequence star such as the Sun burns hydrogen by nuclear reactions. When the Sun begins to burn helium later in its development, it will swell up and become a red giant. The planetary nebulae observed by the IUE are located in the Large and Small Magellanic Clouds, two satellite galaxies of our Milky Way.

The investigators at GSFC discovered that the three planetary nebulae which they observed each contain

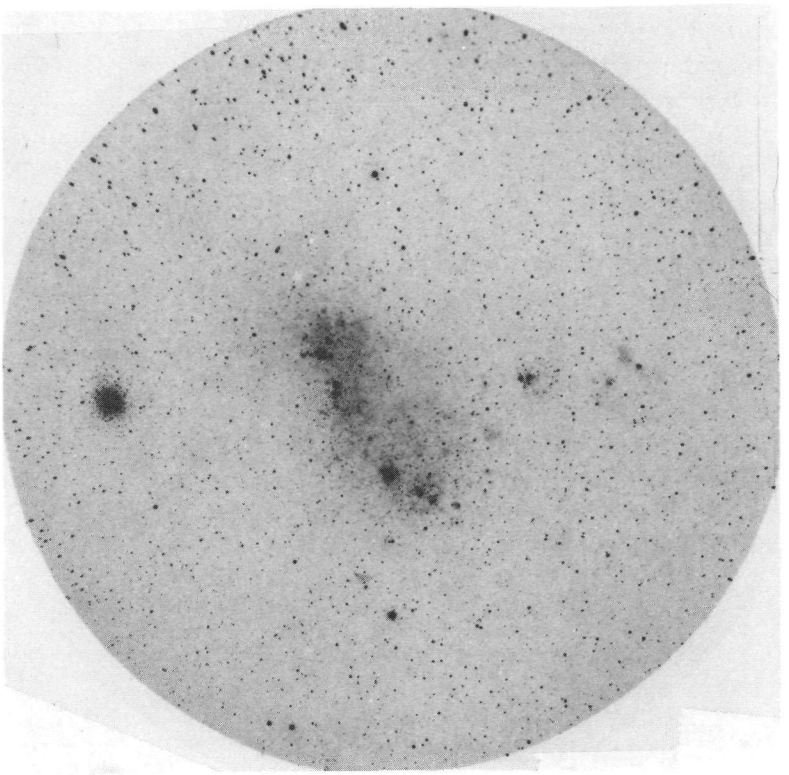


*The first ultraviolet spectra of individual stars in the galaxy M33 have been obtained by IUE.*

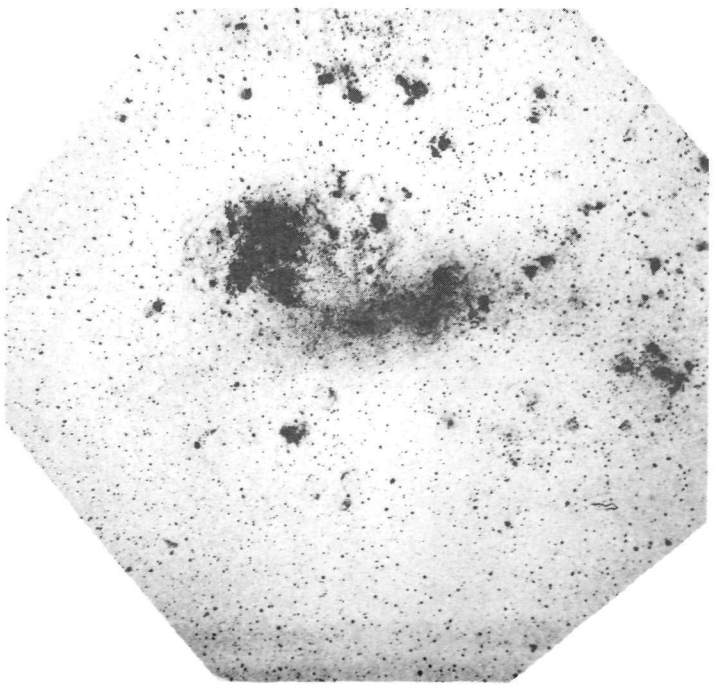
about the same fraction of carbon as similar nebulae in our Milky Way, although the interstellar gas of the satellite galaxies contains much less carbon than the interstellar gas of the Milky Way. Stars all form from instellar gas. Thus, the excess carbon in planetary nebulae must have been created by nuclear reactions within the parent ed giant stars. The investigators concluded that the IUE observations verify the "convective dredgeup theory," which states that carbon created in he central cores of red giant stars is noved outwards to the upper layers y large-scale gas motions. They further concluded that the theory applies o stars of diverse original chemical omposition in our own and other alaxies.

ponsor: Office of Space Sciences
Laboratory for Astronomy and Solar Physics
ontact: Goddard Space Flight Center
Mr. Stephen P. Maran
elephone: (301) 344-8607





*This figure shows the Small Magellanic Clouds observed by the IUE in nearby galaxies.*



*This figure shows the Large Magellanic Clouds observed by the IUE in nearby galaxies.*

### IUE Used to Study Double Stars

The binary star system Zeta Aurigae is the prototype for a group of ecliptic binary systems that consist of a late-type supergiant star and a much smaller, early-type companion. Before and after total eclipse, the light of the companion passes through the extended atmosphere and stellar wind plasma of the supergiant, in what is called the atmospheric eclipse. Temporal changes in the spectrum of the system are caused by the spatial structure of the supergiant's atmosphere.

The International Ultraviolet Explorer was used to monitor the changing spectrum of the binary star Zeta Aurigae as its two stars travelled their orbits. Passing beyond the cool, extended gaseous atmosphere of the red supergiant primary star, its hot blue companion acted as a source of stimulating radiation which enabled astronomers to diagnose the physical conditions in the unusual supergiant star. Thus, the companion star functioned effectively like an arc lamp or laser that is used by chemists to investigate gas properties in a laboratory vessel.

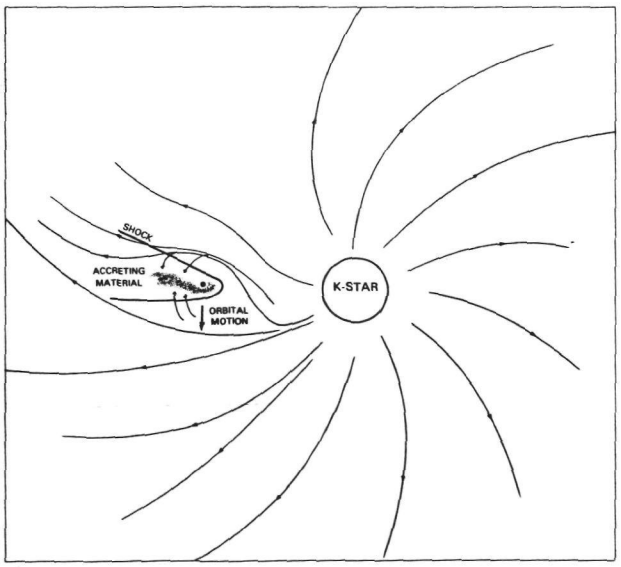
Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. Robert D. Chapman
Telephone: (301) 344-8701

### Detector Studies of BL Lacertae Objects Yield Information on Galaxies

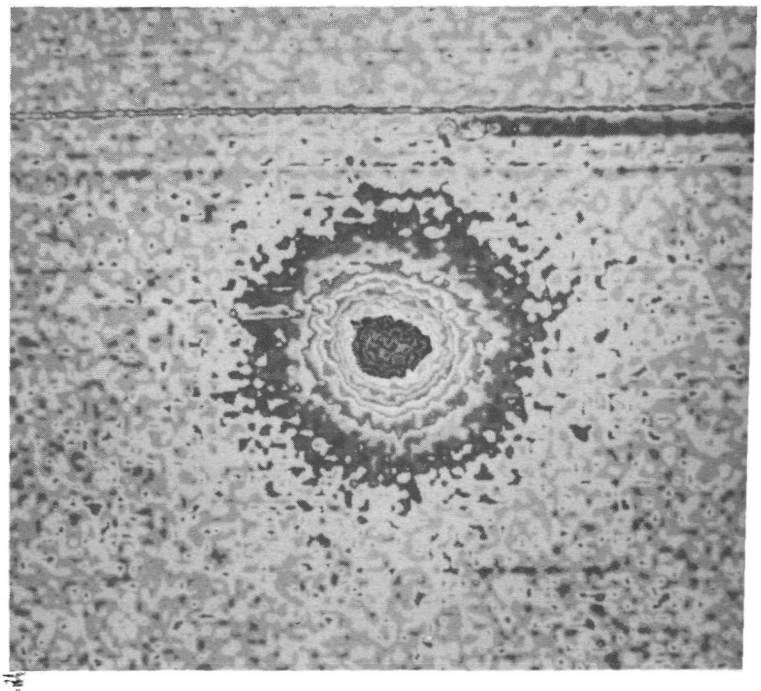
BL Lacertae objects are bright point sources which may play a significant role in evolution of galaxies. They belong to a class of astronomical objects having the following characteristics: they exhibit rapid variations in intensity at radio, infrared and optical wavelengths; most of their energy is emitted in the infrared; there is an absence of discrete features in their low-dispersion spectra; and they show strong and rapidly varying polarization at visual and radio wavelengths. A new two-dimensional electronic detector has been used to observe several of these objects, one of which is associated with a normal galaxy.

The characteristics of a faint source near a second BL Lacertae object indicates it is not a galaxy, as was previously thought. It may be associated with radio emission from the BL Lacertae object. For a third object, the first unambiguous evidence of an associated galaxy has been obtained. Using two-dimensional models of the light distribution, one can estimate the distance to the object. This is a tremendously important technique, since for many BL Lacertae objects, distances cannot be determined using normal methods. The data can also be used to eliminate from consideration certain models of BL Lacertae objects.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Ms. Donna E. Weistrop
Telephone: (301) 344-5781




*Schematic picture of the binary star system Zetz Aurigae.*

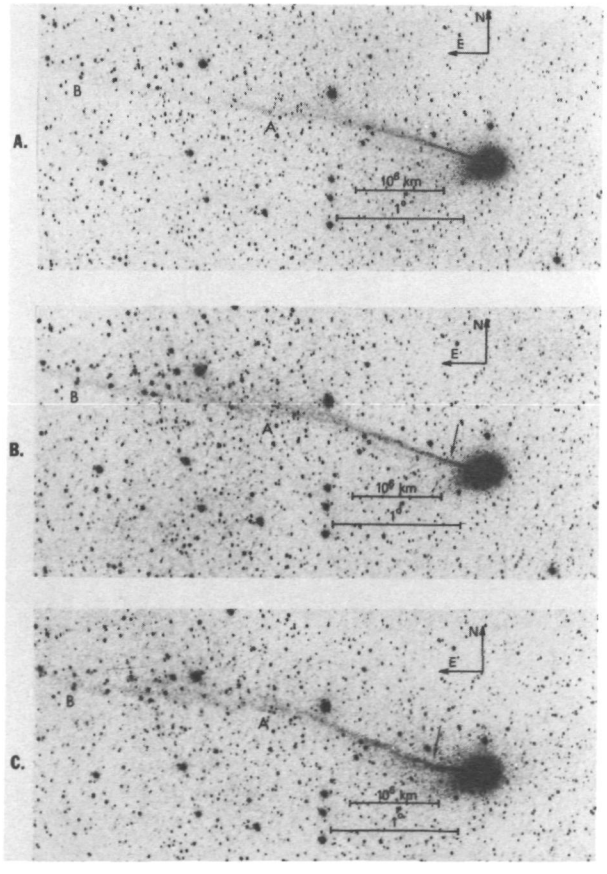


*Images of BL Lacertae objects as obtained with a new two-dimensional electronic detector.*

### Comets Serve as Probes of the Solar Wind

Schmidt camera photographs of Comet Bradfield obtained at NASA's Joint Observatory for Cometary Research show a rapid change in the comet's plasma trail over a short period of time. The sequence of photographs spans 27.5 minutes (top to bottom) and shows a dramatic $10^{o}$ turning of the plasma tail axis. The speed of this tail-turning event greatly exceeds the turning speed of any other known event in comets and even exceeds the turning rates for individual tail streamers. The event can be understood if the plasma tail is considered to be a "wind sock" in the solar wind. The geometrical circumstances were such that the orientation of the tail on the plane of the sky was almost totally determined by the polar component of the solar wind velocity. A simple analysis indicates that a 50 km/sec change in the polar component from about 30 km/sec northward to about 20 km/sec southward would have produced the $10^{o}$ turning. Such events in the solar wind are rare, but known. This is the first time such a rapid event has shown up in comet tail photography. It is remarkable that the comet tail responds so rapidly, and this event underscores the value of comets as probes of the solar wind.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Malcolm B. Niedner, Jr.
Telephone: (301) 344-5272




*Sequence of Schmidt camera photographs of Comet Bradfield spanning 27.5 minutes (top to bottom) showing rapid change in Comet's plasma tail.*

## HIGH ENERGY ASTROPHYSICS

Research in high energy astrophysics at GSFC has emphasized the study of basic problems, whose solution will both assist us in obtaining a better understanding of the universe and its components and guide us in planning new astrophysical observations.

### Cosmic Ray Observations In The Distant Heliosphere

The observations of Pioneer 10 and Helios 1 and 2 of the intensity changes of galactic cosmic rays associated with the enhanced solar activity during the onset of cycle 21 over an extended range of energy and heliocentric distance provides new insight on the relative importance of the various processes involved in the long-term modulation. There is close correspondence between changes at 1 AU and those at 23 AU for hydrogen and helium in the range of 100-200 MeV per nucleon. The relative decrease is of the same order at both locations with an appropriate time delay that corresponds to an outward propagation velocity of some 500 km $s^{-1}$. These measurements suggest that the recently discovered, moderately long-lived, radially propagating shock waves in the outer heliosphere play a key role in the long-term modulation. At the location of Pioneer 10, the variations in the intensity of the anomalous and galactic cosmic-ray helium are well correlated.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Frank B. McDonald
Telephone: (301) 344-8801

## Gamma Ray Spectroscopy and Transient Studies

During the last year several advances have been made in the fields of celestial gamma ray spectroscopy and of gamma ray transient astrophysics. The GSFC high energy astrophysics program in high-resolution gamma ray spectroscopy provided, from a balloon-borne exposure, definite evidence for time variability in the cyclotron resonance spectral feature of the source Her X-1. The sensor used was an intrinsic germanium spectrometer with a differential spectral capability far exceeding that of the scintillator used by the MPI group to make the discovery of the cyclotron resonance phenomenon, yet no line features were observed, indicating extreme temporal and/or spectral variability.

The program in gamma ray burst astrophysics has defined a burst source location in close association with an unusual radio source, detected with the VLA. A repeated radio exposure, if indicating time variability or proper motion over a several year interval, could provide the missing link for source identification by connecting the $\gtrsim$ 1 arc $min^2$ burst source boxes to $\lesssim$ 1 arc $sec^2$ phenomena in the radio regime. As reported last year, a very small 0.1 arc $min^2$ error box was defined for the March 5, 1979 transient; this region has been surveyed in a repeated Einstein Observatory X-ray exposure, to search for time variability, but none was detected. The study of this event is, however, helping to prompt the present theoretical development of several new processes.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Thomas L. Cline
Telephone: (301) 344-8375

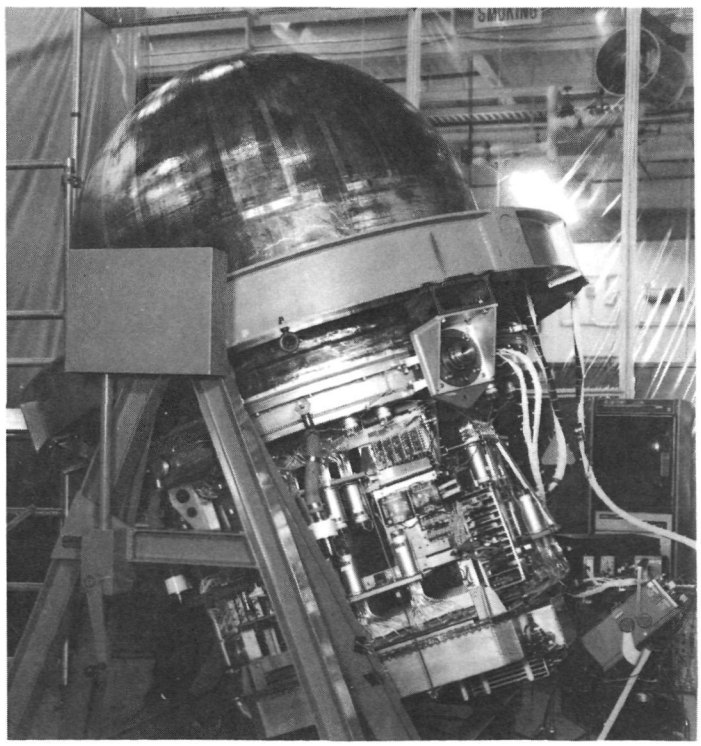
## Gamma-Ray Astronomy

The high energy gamma-ray telescope, which is a joint effort of the Max-Planck-Institut fur Extraterrestrische Physik, Stanford University, Grumman Aerospace Corporation, and Goddard Space Flight Center, was accepted for flight on the Gamma Ray Observatory (GRO). This instrument will have a much greater sensitivity and improved energy and angular resolution compared to earlier high energy gamma-ray satellite telescopes. Although funds have been constrained, work is well underway.

During the last year a detailed study of the gamma radiation due to galactic cosmic ray electrons interacting with optical, infrared and black body photons was completed. It showed that future energy spectral and latitude studies should be able to separate the galactic Compton radiation from that due to cosmic ray matter interactions. New analyses of the galactic and extragalactic diffuse radiation are in progress, and analysis of the data from the medium energy gamma ray balloon flight is well along with the galactic ridge already apparent.

The high energy gamma ray balloon instrument was completed in 1981 and will be flown next year. This telescope incorporates many of the systems to be used on the GRO high energy gamma ray telescope. Because of limitations imposed by the atmosphere and the length of balloon exposures, it will be used primarily to try to obtain accurate locations of the stronger gamma ray sources such as ($\ell$-195, b=5). Work now has begun on the Advanced Compton Telescope to be used in the study of the intermediate gamma ray range.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Carl E. Fichtel
Telephone: (301) 344-6281



*The Gamma Ray Telescope, to be flown on the GRO, will be used primarily to obtain accurate locations of strong gamma ray sources.*

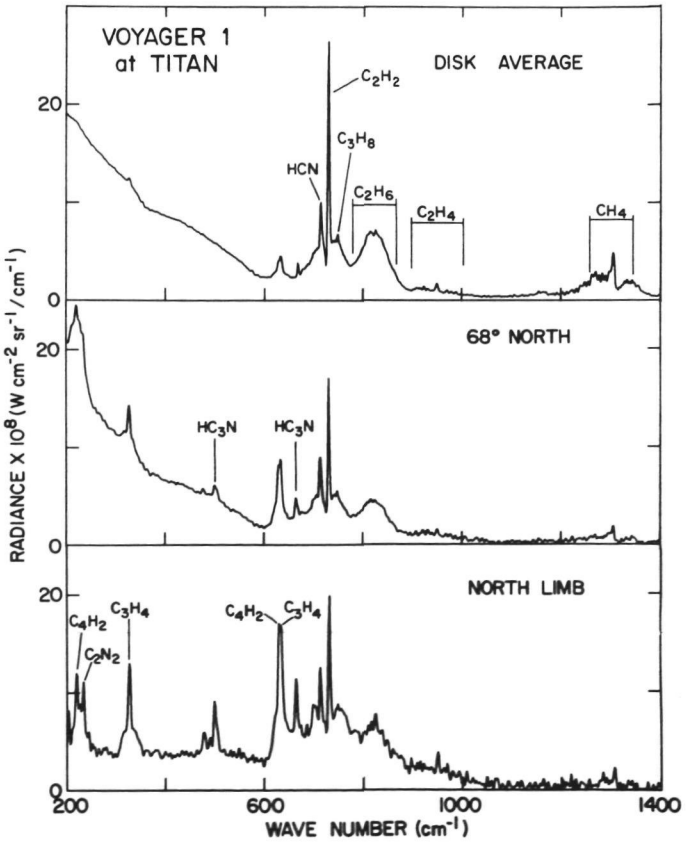
### nfrared Spectroscopy of Saturn and itan on Voyager 1 and 2

A Goddard scientific team, led by r. Rudolf Hanel, built the infrared pectrometers flown on the Voyager ission. In the past year, the team's vestigations centered on data re- rned from the encounters of the aturnian system. Observations of aturn's atmosphere confirm the pre- nce of molecular hydrogen ($H_2$), ethane ($CH_4$), acetylene ($C_2H_2$), hane ($C_2H_6$) and ammonia ($NH_3$). s anticipated, $NH_3$ was found to be bstantially less abundant in the pper atmosphere of Saturn than in at of Jupiter because of Saturn's oler temperatures. A strong North- outh assymetry in the thermal struc- re of Saturn's upper atmosphere has een found, which is believed to be a asonal effect similar to Earth's. mall scale latitudinal temperature gradients were found, suggesting that the system of alternating eastward and westward jet streams deduced from Voyager images decreases in intensity with height as on Jupiter. However, the data indicates a continuation of the jet system into the polar region on Saturn, unlike Jupiter where the jets are confined to a region within 60° latitude of the equator.

Significant new data has been obtained on Titan, Saturn's largest moon and the only moon possessing a substantial atmosphere. In addition to methane and acetylene, which were already known to be present in Titan's atmosphere, $H_2$ and several hydrocarbons, including ethylene ($C_2H_4$), ethane ($C_2H_6$), methylacetylene ($C_3H_4$), propane ($C_3H_8$) and diacetylene ($C_4H_2$), were discovered. The nitrogen-containing molecules hydrogen cyanide (HCN), cyanoacetylene ($HC_3N$), and cyanogen ($C_2N_2$) were also found by Voyager; these are of particular interest, since they are prebiological building blocks which were probably also present on the primitive Earth.

At high altitudes, where the numerous complex molecules are formed, eastward-blowing winds of 200 miles per hour are present. Below this, Titan's cold surface (-290°F) and lower atmosphere (as cold as -325°F) may permit the formation of unusual liquid clouds; such clouds would be mostly methane, but would also contain as much as 20% dissolved atmospheric gases, such as nitrogen and argon.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Rudolf Hanel
Telephone: (301) 344-8528




*ectra from different cations on Titan, owing the spectral es which are due to e presence of the ny nitrogen contain- and hydrocarbon lecules in Titan's nosphere. Molecular drogen caused the llow dip centered at 4 $cm^{-1}$ in the Disk erage spectrum.*

### High Energy Cosmic Rays

A large Cherenkov apparatus is being built to explore the energy dependence of the source composition of cosmic ray nuclei with charges in the range from 15 to 30. The balloon-borne experiment will make use of several novel techniques to identify individual nuclei of these rare particles. Among these is the use of a hodoscope array of triangular scintillators to compose a large area detector which is sensitive to both the charge and trajectory of incident cosmic rays. Photon statistics and hence the energy resolution of the Cherenkov device have been optimized by the use of surface-applied organic waveshifters to convert ultraviolet Cherenkov light to wavelengths to which photomultipliers are most sensitive. This allows the experiment to operate in the several hundred GeV/amu range, the highest energy at which direct measurements of composition have been made. Results from the 1982 flight should improve our understand-

ing of the processes of particle acceleration on the galactic scale and the storage mechanism of cosmic rays in the galactic magnetic field.

The storage mechanism and the distribution of sources in the galaxy are also reflected in the details of the composition of the particles in the 1 to 10 GeV range. Analysis of new data obtained by the Danish-French Cosmic Ray experiment on HEAO-3 has enabled tight new constraints to be placed on the models using this data. The analytic techniques which have been used to study the propagation of nuclei in interstellar medium are also being used to test the change in composition with depth in the atmosphere. With these results, abundances obtained on balloon-borne experiments can be extrapolated to the top of the atmosphere with sufficient accuracy to test theories of cosmic ray origin and propagation.

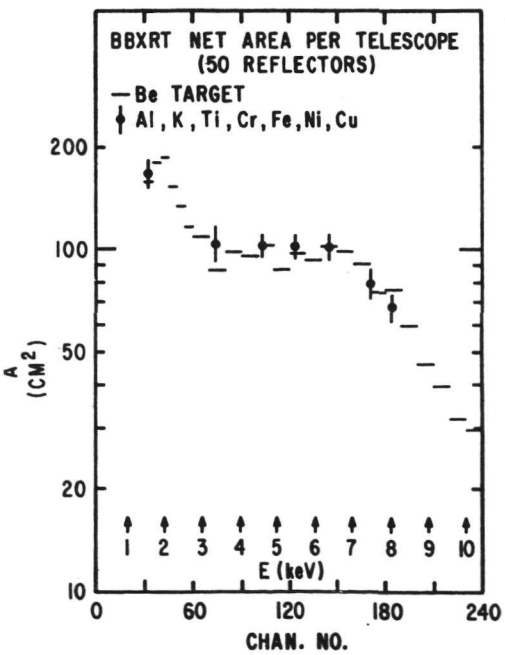
Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Jonathan F. Ormes
Telephone: (301) 344-5798

## X-Ray Astronomy

Results obtained for a wide range of X-ray sources, extending from stellar coronae to clusters of galaxies, point to the need for line spectroscopy over a broad band as a follow-up to our HEAO (1 and 2) experiments. To this end, the Goddard X-ray group is presently developing a Broad Band X-Ray Telescope (BBXRT) experiment which was successfully proposed for the Spacelab program.

Efficiency tests have been carried out on the inner most 50 reflectors of the array comprising a net geometric area of 220 $cm^2$. They have demonstrated, for the first time, that the new reflector preparation process results in a surface comparable in smoothness with highly polished optical flats. The measured effective area as a function of energy is shown in the accompanying figure. It allows us to infer the total effective area for the 2 BBXRT mirrors at $\sim$ 1000, 400, and 200 $cm^2$ at corresponding energies of 2, 4 and 7 keV. These values surpass our initial goals as stated in the Spacelab proposal and confirm that BBXRT can be a powerful tool even in a short duration shuttle flight. For example, 2000 s exposures are adequate to measure the spectra of quasars at flux levels $\sim 10^{-12}$ ergs/$cm^2$-s or to detect iron lines in Perseus-like clusters of galaxies out to a redshift of $\sim$ .2. Our measurements further indicate that the novel telescope design would be a serious candidate for a future free-flying mission conceived for high throughput over a broad energy band at an angular resolution of $\sim$1 arc minute.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Peter Serlemitsos/
Dr. Elihu Boldt
Telephone: (301) 344-5255/344-5853




*Graphic display of the results from a measured area taken with the Broad Band X-Ray Telescope (BBXRT).*

## Gamma Ray Lines From Solar Flares

The interactions of energetic particles with the solar atmosphere produce a rich spectrum of gamma ray lines. The theory of the line production, worked out in considerable detail over a period of several years, has been put to observational test by the recent gamma ray spectroscopy results from the Solar Maximum Mission. The strongest line of the theoretically predicted solar gamma ray spectrum, at 2.223 MeV from neutron capture in the photosphere, has been seen from many flares. Several other strong lines, e.g. those at 6.13 MeV from $^{16}O$, 4.44 from $^{12}C$ and 0.511 MeV from positron annihilation, are also observed. Solar gamma ray observations open a new channel for the study of the acceleration and interaction of solar energetic particles, provide unique information on the flare mechanism, and permit the spectroscopic determination of certain isotopic abundances (e.g. $^{3}He$) that cannot otherwise be obtained.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. Reuven Ramaty
Telephone: (301) 344-8715

## MAGNETOSPHERES AND SPACE PLASMA PHYSICS

During the past year, Goddard scientists have pursued a variety of research efforts concerned with the study of the interplanetary medium, planetary magnetospheres and solar-planetary relations. Investigation of physical processes in the terrestrial magnetosphere and nearby solar wind continued using measurements from instruments aboard the Interplanetary Monitoring Probe 8, International Sun-Earth Explorer 1 and 3 and Scatha spacecraft, and a whole new dimension to our study of coupling between the Earth's magnetosphere and upper atmosphere was opened by the successful launching of the Dynamics Explorer satellites. Analysis of the interplanetary medium in regions far from Earth was made possible by measurements collected by Goddard instruments aboard Helios and Voyager. Two Voyager spacecraft encounters with Saturn lead to a number of new discoveries concerning the properties of plasmas in Saturn's space environment. Complementing the research activities associated with these flight programs are a number of theoretical studies, sounding rocket experiments and instrument development programs that provide a means of enhancing the returns from prior programs and advancing our capability for future advances.

### Magnetospheres

In FY 1981 the adiabatic theory of charged particle motion has been developed for rapidly rotating magnetospheres. The designation "rapid rotation" is not an absolute one, and depends on the particle studied. Rotation is "rapid" whenever the particle gyro velocity is less than or comparable with the local corotation velocity of the magnetosphere. The particle trajectory then is an open cycloid ∿∿ rather than a looping one ⌀⌀. A sulfur ion picked up cold from Jupiter's moon Io has an open trajectory. The second adiabatic "invariant" is normally not invariant for an open cycloid trajectory. Nevertheless its invariance was assumed by several authors in their analyses of the diffusive motion of these Sulfur ions.

What we have discovered is that in the special case of a rigid rapid rotator, which is an arbitrary magnetic mirror geometry that possesses an intrinsic form that merely rotates in time, the second "invariant" is in fact invariant. This comes about because for a rigid rotator the exact particle equation of motion in the rotating frame is formally identical to that for a looping trajectory. Thus all of previously derived theory for non-rotating systems is applicable to rigid rapid rotator (such as Jupiter or Saturn), including proofs of the adiabatic invariants. In the rotating frame the particle slowly drifts around its second invariant surface, while the surface rotates rapidly with the planet.

This work has also laid to rest at least a question that has lurked in the background since the beginning of the space age: Can an arbitrary wobbling, asymmetric magnetosphere pump particles up in energy on a long term time scale? Detailed calculations in very special geometries have answered "No". The present work says "no" for the general case, too. An exact constant of the particle motion plus the existance of the second invariant is sufficient to establish this fact.

The theory has been extended to micron size charged dust grains, such as constitute the "spokes" of Saturn and the halo surrounding Jupiter's ring. The analysis is now greatly complicated by the facts: (1) the gravitational field matters (2) the charge on the grain varies at its gyrofrequency due to the presence of a plasma (3) the orbits are typically open cycloids even in the corotating frame (no second adiabatic invariant). Analysis shows that dust grains will migrate radially inward if they are outside synchronous orbit, and radially outward when inside. They will stop their radial migration and settle into circular orbits about the planet before reaching synchronous orbit however. Thus dust grains injected by Io's volcanoes probably cannot get into Jupiter's ring, which is inside synchronous orbit. However this statement is based on a study of equatorial plane orbits only, so far. Bouncing motion along the field lines and the $10^{o}$ Jovian dipole tilt may change this conclusion.

We have applied this dust grain theory to pictures of Saturn's "spokes" taken by Voyager. The grains have a charge to mass ratio of the order of 25 coulombs/kilogram, according to our theory.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. T. G. Northrop
Telephone: (301) 344-7266

### Dynamics Explorers Launched

After many years of planning and development, the Dynamics Explorer (DE) satellites 1 and 2 were successfully launched on August 3, 1981, into coplanar polar orbits. During the development of the program, several activities were initiated which are unique in their support of such missions and their associated scientists. Since key to the success of the mission is the operation of the two spacecraft in conjunction with each other, science operations must be carefully planned. For this purpose, a Science Operations Planning Office was established. The Science Operations Planners produce daily operations schedules for the spacecraft, based on generalized plans

from the Science Team, orbital configuration predicted by the NSSDC Satellite Situation Center, and specific operational requirements from the scientists.

The quality of data being returned by the instruments is superb. In order to make data sets from multiple instruments available for analysis, a graphics system was developed to display key parameters from the instruments on both spacecraft. These plots enable the scientists to identify key events or time periods for which data from several instruments are needed. The plots are being generated on a project micrographics unit, which is available to all program scientists for graphic displays on microfiche, microfilm and movie formats in grey scale or color. Finally, the pioneering centralized ground data processing system of the Atmosphere Explorer program has been acquired by the Project and upgraded in several important ways. All the remote terminals of the Investigators' facilities have been replaced with graphic terminals, including grey scale and color. Especially important has been the development of the Mission Analysis File system with accompanying directory. These files of processed data are available to all the scientists along with plotting routines from the responsible instrumenters. The directory entries not only identify the contents of a file but can be used for sorting data types.

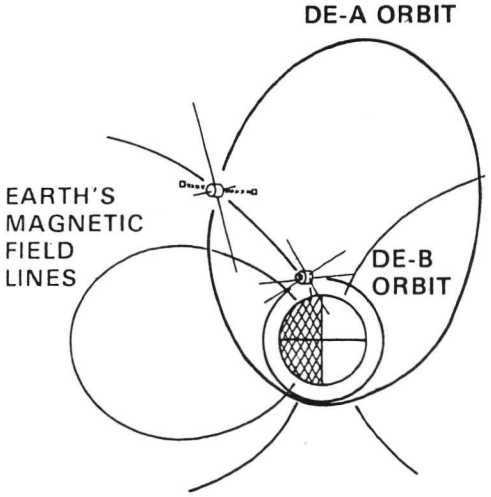
Very initial results from the program have indicated that the mission will be a powerful tool in our quest for understanding the Earth's near space environment.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Cente
Dr. R. A. Hoffman
Telephone: (301) 344-7386

## Electric and Magnetic Fields in the Earth's Magnetosphere

Simultaneous measurements have been taken by the electric field probe and the magnetometer on the Dynamics Explorer (DE)-2 spacecraft, several days after the deployments of these instruments are already providing important new information. Strikingly similar variations have been seen in the electric field and the magnetic field as the spacecraft crossed the polar regions and sampled magnetic field-aligned currents in the dayside cusp. The capabilities of correlative investigations using observations of different physical parameters from each of the two DE spacecraft (and from a combination of them) are unique in this mission. Such comprehensive correlative studies will help us achieve a new understanding of the coupling processes of the atmosphere, ionosphere and magnetosphere.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. M. Sugiura
Telephone: (301) 344-5839




*Schematic diagram of the Dynamics Explorer Satellites co-planar orbits around the Earth.*

## Measuring Magnetic Helicity

As part of an effort to explore the nature of solar wind magnetic and plasma fluctuations Goddard scientists have developed a technique for measuring the "magnetic helicity" of a turbulent magnetic field. The magnetic helicity is a measure of the topological properties of a magnetic field. If field lines are knotted, linked or otherwise not superimposable on their mirror images, the field is "helical". By using measurements of interplanetary magnetic fields obtained with the Goddard magnetometers on Voyagers 1 and 2, the magnetic helicity spectrum of the solar wind has been measured for the first time. A large number of theoretical developments in fusion-oriented plasma physics deal in predictions concerning the behavior of helicity. Despite all of this theoretical interest, comparison of theory with experiment has been completely lacking because helicity has never been directly measured until now.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. M. L. Goldstein
Telephone: (301) 344-7828

## Radio Astronomy Measurements of Saturn

The Voyager radio astronomy observations of Saturn have yielded a fascinating view of that planet's radio emissions. The intense, kilometer wavelength noise bursts were first discovered by Voyager in early 1980 and by utilizing data from the two Saturn encounters Goddard scientists have been able to locate the source of the radiation in two relatively small regions on the planet. One source, the stronger of the two, is in the northern hemisphere, and the other is in the southern hemisphere. Both sources appear to be coincident with region

near the poles of the planet where magnetic field lines tend to open up into the interplanetary medium and where auroral activity occurs. Since planetary rotation acts to turn the emissions on and off, the radio sources have also been localized to specific longitudes on the planet, possibly where weak anomalies exist in the surface magnetic field. The radio sources are usually very intense, generating giga watt power levels; however, Voyager-2 observations showed that they would sometimes shut off completely for several days. No other radio planet, neither the Earth nor Jupiter, has ever been observed to vary so dramatically.

When Voyager-2 crossed the plane of Saturn's rings the planetary radio astronomy instrument detected a unique burst of radio noise that extended over a broad band of frequencies for an interval of 2-1/2 minutes. This noise was apparently caused by the direct impact of tiny particles against the spacecraft as it traversed the region just outside the visible rings. The duration of the radio noise event has been interpreted to show that the total vertical thickness of the 'invisible' G-ring is more than 1500 km – much greater than the visible rings closer to Saturn.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. M. D. Desch
Telephone: (301) 344-5884

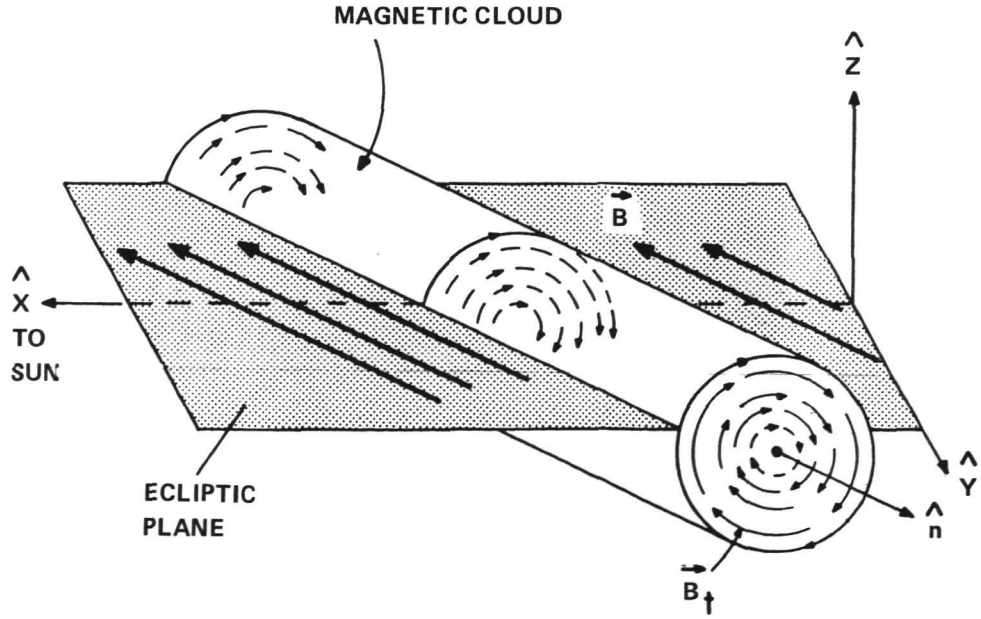
**Magnetic Loops In The Solar Wind**

The solar wind is a hot magnetized plasma which continually moves away from the Sun at supersonic speeds. Occasionally this quasi-stationary wind is interupted by flows consisting of material and magnetic fields ejected by violent processes on the Sun such as solar flares and eruptive prominences. The structure of the magnetic fields in these ejecta has long been a subject of speculation until recently.

A new class of solar wind transients, characterized by strong highly-ordered magnetic fields with unusual directions and by plasma with relatively low temperatures, was identified in earth-orbiting IMP spacecraft. Goddard investigators have shown that the direction of the magnetic field rotates smoothly as such a "magnetic cloud" moves past the spacecraft, in a way that is consistent with passage of a magnetic loop. Taking advantage of the measurements provided by the IMP series of spacecraft over more than a decade, it was possible to show that these magnetic clouds move past Earth at the rate of at least 1 every 3 months. This is consistent with the rate at which coronal mass ejection events are seen at the Sun, suggesting a possible relation between interplanetary magnetic clouds and coronal transients. This association is being studied using data from Helios 1, which currently spends much of the time in its orbit over the limbs of the Sun, and is thus ideally situated for correlations with white-light observations.

The pressure inside magnetic clouds at 1 astronomical unit (AU) was found to be higher than that in the surrounding solar wind, indicating that they are expanding. Using Voyager spacecraft data it was shown that this expansion continues at least out to 4 AU.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. L. F. Burlaga
Telephone: (301) 344-5956




*Schematic diagram of a Magnetic Cloud and how it rotates.*

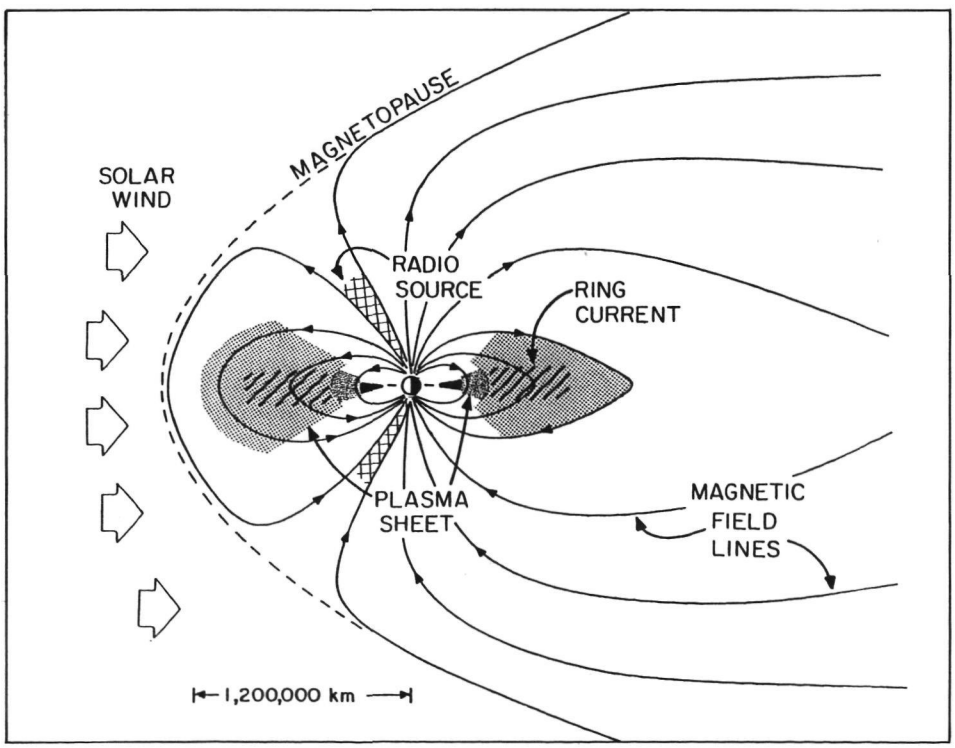
## Magnetic Field Measurements in Saturn's Magnetosphere

Magnetic field measurements obtained by the Goddard magnetometer aboard Voyagers 1 and 2 at Saturn have revealed a giant ring of electrical currents that flow around the planet. This magnetic ring current fills a region outside the visible rings at distances extending from about 8 to 16 Saturn radii from the planet and some 2-1/2 Saturn radii above and below the equatorial plane. A total of about 7 million amperes flows in this current.

The Voyager magnetic field observations also discovered small amplitude waves moving in a direction away from the Sun along the boundary of Saturn's magnetosphere. They may be similar to waves set up by the wind blowing across the surface of a pond. In the case of Saturn the surface waves are thought to be driven by the rapid rotation of Saturn's magnetosphere.

Among the most enigmatic aspects of Saturn's magnetic field is the finding that the magnetic dipole axis is almost perfectly aligned with the planetary spin axis. Since the intense magnetospheric radio emissions measured by Voyager wax and wane dramatically as Saturn rotates, the magnetic field was expected to show a significant tilt or other asymmetry that would modulate the radio emissions at Saturn's 10 hr 39 min rotation period. Lacking any such distortion or tipping of the planetary magnetic field, Goddard investigators are now seeking other, more subtle explanations for the periodic variations in the radio emissions.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Dr. J. E. P. Connerney
Telephone: (301) 344-5884

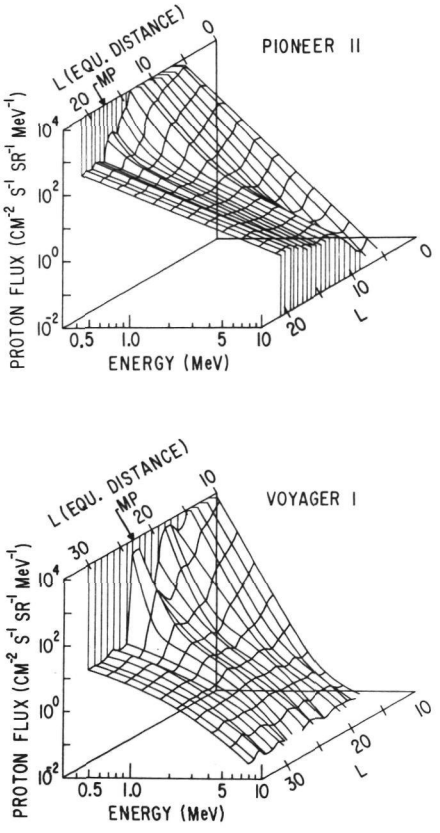



*This schematic view of Saturn's magnetosphere was derived form Voyager.*

## Saturn's Magnetosphere

An intensive effort was made to analyze the energetic particle data obtained in the magnetosphere of Saturn. The Pioneer 11 encounter occurred in September 1979, the Voyager 1 encounter in November 1980, and the Voyager 2 encounter in August 1981. Defined were the energetic particle fluxes, spectra, angular distributions and temporal variations. Using these results, studies of the corotation of the magnetosphere with Saturn, the interaction of this radiation with Saturn's moons and rings, and the access of solar cosmic rays to the magnetosphere. The radial dependence of the phase space density demonstrated that the particle population in the outer magnetosphere was derived from inward diffusion and accompanying acceleration; however, a second source is required to account for the energetic proton fluxes in the inner magnetosphere.

To minimize the effect of different spacecraft latitudes, the distance is given in terms of L, which is the equatorial distance of a dipole field line going through the spacecraft. Inside the magnetosphere, two distinct proton components are present. A very steep low energy component with a spectrum $j(E) \propto E^{-\gamma}$ and a high energy spectrum above ~2 MeV. The high energy spectrum has the same shape and almost the same intensity as the interplanetary solar proton spectrum which had been observed prior to passage through the magnetopause. Surprisingly, the solar proton spectrum penetrated the magnetosphere to $L < 10$, this is well inside the Stormer cut off of Saturn's magnetic dipole field. From this observation on Pioneer 11, it was postulated about the existence of a magnetotail which could provide the required access. This conclusion was confirmed by Voyager 1.




*These figures illustrate the changes in the proton spectra and fluxes as a function of distance from Saturn, as observed during the inbound passes of Pioneer II and Voyager 1.*

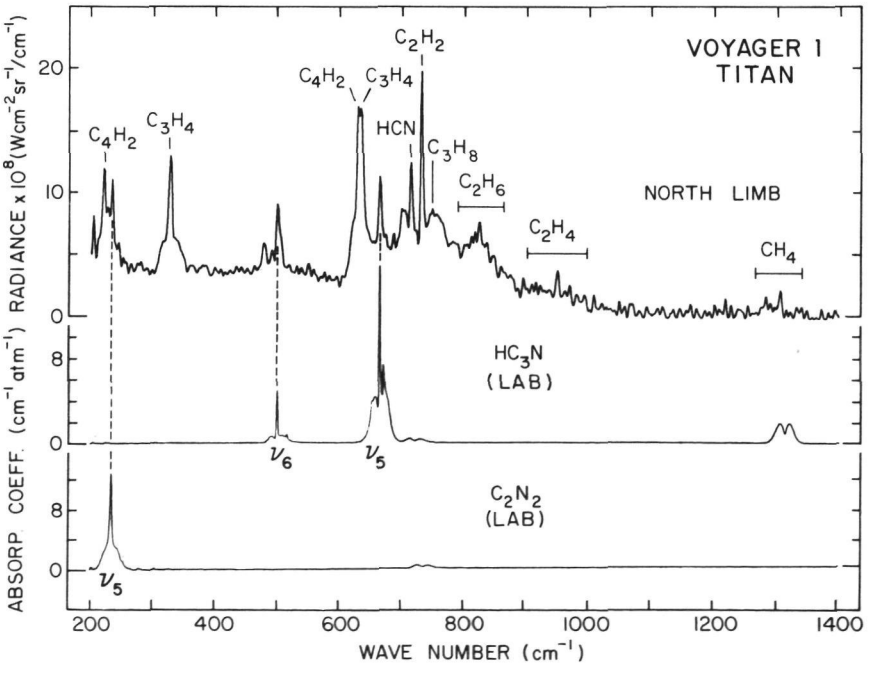
The transition energy between the two proton components gives a measure of the highest proton energy which is trapped in the magnetosphere. As would be expected, this energy increases toward the planet. The trapping energy depends on the magnetospheric configuration and was lower during the Pioneer 11 encounter when the magnetosphere was compressed. Temporal changes in the solar wind modulate the cut off energy and we believe that this modulation is largely responsible for the large temporal changes in low energy flux that can be seen in the figure and are even more pronounced in the Voyager 2 data.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. A. W. Schardt
Telephone: (301) 344-5705

## Infrared Laboratory Spectroscopy For Interpretation Of Titan Spectra

Titan's infrared spectrum showed emissions rich in compounds of hydrogen, carbon, and nitrogen. Although some compounds were recognizable from earlier laboratory spectroscopy, others could not be associated with observed emission features because of inadequate supporting laboratory measurements. A Goddard scientist quickly measured laboratory infrared spectra for a number of complex molecules suspected to be present in the Voyager infrared spectra. These rapid measurements enabled timely identification and abundance estimates to be made by the Voyager team.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Dr. Donald Jennings
Telephone: (301) 344-7701




*Identification of rich atmospheric compounds around Titan was made possible by rapid measurements with the Infrared Laboratory.*

## Jupiter's Magnetosphere

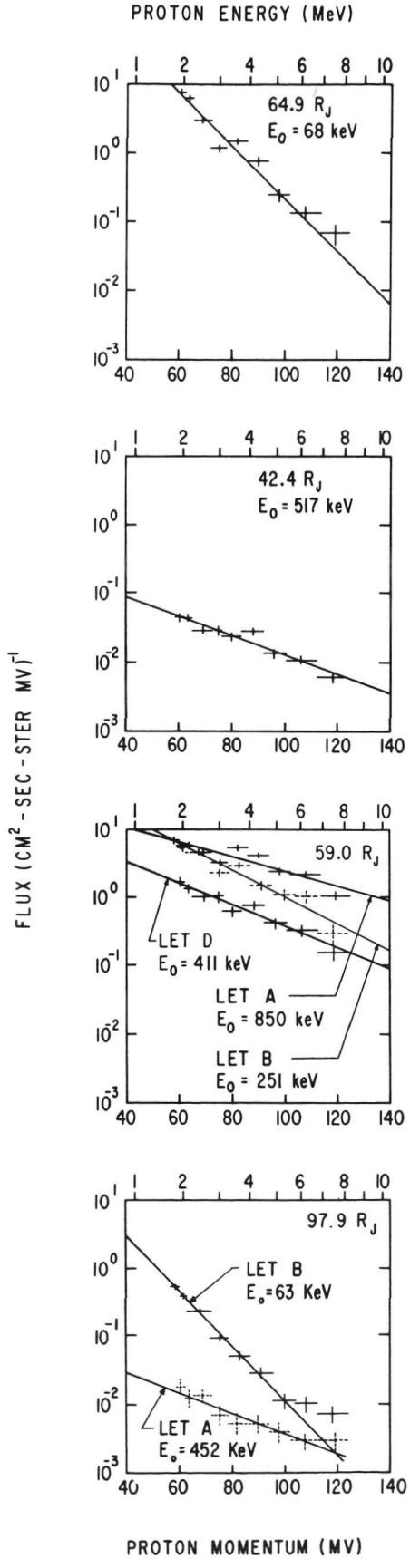
The energetic particles in the Jovian magnetotail were studied on the basis of CRS data from Voyagers 1 and 2. The variety of phenomena studied may be exemplified by a discussion of proton fluxes and spectra. Field lines that cross the plasma sheet in going from the northern to southern hemispheres are able to trap protons. The quiescent spectrum of trapped protons is illustrated in the top graph. Their spectrum is of the form $j(p) \propto e^{-p/p_0}$, where p is the proton momentum and $E_0 \propto p_0^{2/m}$ is the energy that characterizes the slope of the spectrum. The quiescent spectrum is almost constant out to the magnetopause, and the intensity decreases only slowly with distance. Only a few degrees in latitude above or below the plasma sheet, the field lines are open and interplanetary protons have free access. As shown in the second graph, the spectrum is much harder and the flux of 2 MeV protons is only about 1 percent of its value near the plasma sheet.

Different types of proton acceleration can occur in the magnetotail and were observed near the plasma sheet. The one at 59 $R_j$, the third graph, was characterized by a much harder spectrum than normal and large spacial gradients in the proton flux. The spacial gradient can be deduced from the different intensities observed with LET A and D both of which pointed almost perpendicular to the field. LET B pointing parallel to the field direction observed an intermediate flux and spectrum.

At 97.9 $R_j$, the final graph, we observe a high proton flux streaming away from Jupiter along the magnetic field. The intensity observed with LET B varied by orders of magnitude in a few minutes. In contrast, the flux of protons mirroring perpendicular to the magnetic field, as observed with LET A, changed relatively little and the spectrum remained hard.

Another most interesting study is the modulation of interplanetary electrons emitted by Jupiter. An epoch analysis has been performed of Voyager 1 and 2 electron fluxes observed after the Jupiter encounter. This shows a 9hr 55m modulation of the spectral index of the electron flux between 2.5 and 13 MeV. The softest spectrum is observed when the Jovian longitude $\lambda_{III} = 240^0$ (1965) has rotated into the subsolar direction. The modulation can be identified out to at least $10^8$km from Jupiter. The depth of modulation varies and may depend on interplanetary conditions.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. A. W. Schardt
Telephone: (301) 344-5705




*Proton fluxes and spectrum studies conducted with Voyager 1 and 2 on Jupiter's Magnetosphere.*

## SCIENCE SUPPORT ACTIVITIES

For scientific data to be usable, it s essential that improvements be made in data analysis, handling and distribution. The support activities of GSFC in Fiscal Year 1981 are described below.

### Science and Applications Computing Facility

The Science and Applications Computing Center provides general purpose computational services to support scientific research at Goddard. During FY81 a procurement was completed to replace the aging central computers in the facility in order to satisfy more effectively scientific computing requirements in the 1980's.

The replacement will be phased over several stages beginning with installation of an initial IBM 3081 processor and supporting peripherals in October 1981. The 3081 is IBM's most advanced mainframe processor and utilizes a highly integrated circuit technology, packaged in Thermal Conduction Modules (TCM's). The TCM s a helium filled, encapsulated module, measuring 125 x 134 x 35 millimeters, and contains tens of thousands of logic circuits. Benefits of this new technology include significant increases in computing capabilities, along with significant reductions in space, power, and cooling requirements.

A key objective in upgrading the computational facility is to enhance unctional capabilities to better support an on-line, interactive environment for scientists and engineers to analyze their data. A critical step in meeting this objective is the planned nstallation of a mass storage device n the fourth quarter of FY82. This nit will ultimately provide on-line torage for 400 billion bytes of data and will serve as a shared resource to be accessed from both the central and distributed processors.

The upgraded computational facility will continue to evolve in a modular fashion in the future, so as to meet new and changing requirements in an incremental fashion and to take advantage of rapid advances in computer technology as they are available.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. J. H. Bredekamp, Jr.
Telephone: (301) 344-8541

### The CDAW Approach to Data Analysis

The Coordinated Data Analysis Workshop (CDAW) approach, in which problem-oriented digital data bases are constructed from multi-source sensors, has continued to progress this year. A new workshop software system that operates on the National Space Science Data Center computer has been completed and offers more flexible graphics capability and much more data manipulation routines. The features of this system have been incorporated into a larger system that can offer device independent plotting routines and a user friendly prompting feature with levels of complexity which correspond to user experience. This large system has been developed on a large IBM mainframe and is readily transportable to the new Sciences Directorate Computer.

The installation of such a system would enable numerous scientists to access coordinated data bases concurrently from their home institutions, greatly facilitating collaborative data analysis. The planning for the sixth coordinated data base (CDB 6) and related analysis activity have been accomplished in FY 81. There are 67 scientists who have indicated their intention to participate. Thirty-one satellite data sets from 11 satellites and 19 data sets from ground-based networks have been promised; at the end of FY 81, 27 data sets had been sent in for CDB-6 construction. The CDB-6 is designed to study the energy transfer mechanism in the geomagnetic tail.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. James I. Vette
Telephone: (301) 344-7354

Page intentionally left blank

Page intentionally left blank

# III Space and Terrestrial Applications

*The major goals and primary thrust of Goddard's Space and Terrestrial Applications activities are to conduct research and technology studies and experiments necessary for the full utilization of space science and technology for applications on Earth.*

*The overall program can be summarized as follows:*

*Observe and study the solid Earth and its oceans from space to better understand and forecast environmental behavior, to assess the productivity of the Earth and oceans for both renewable and non-renewable resources and study the total dynamics of the solid Earth and its oceans.*

*During Fiscal Year 1981, GSFC made important contributions to the overall Space and Terrestrial Application's Program goals through proper use of space science and technology in the following areas:*

- *Atmospheric Sciences and Applications*
- *Upper Atmosphere Research*
- *Planetary Atmospheres*
- *Earth Science and Applications*
- *Sensor Development*
- *Information Extraction*
- *Space Applications Transfer*

## ATMOSPHERIC SCIENCES AND APPLICATIONS

Analyses of the data from the Global Weather Experiment have shown clear evidence of the positive impact of satellite observations on the skill and duration of global weather predictions. A variety of global model experiments has demonstrated the importance of sea surface temperature and soil moisture in controlling climate on monthly to seasonal time scales and provides greater hope for skillful climate predictions. Analyses of satellite and aircraft data, in concert with theoretical computations and modeling experiments, have produced significant progress in the study of cloud parameters and provided new insights into their relationship to the Earth's radiation budget. The first temperature soundings from geosynchronous satellites (GOES-VAS) show accuracies comparable to those from TIROS-N; these and the new imagery in the water vapor band have begun to provide the basis for new understanding and prediction of severe storms and other mesoscale events. Stereo mapping of cloud top topography from two SMS/GOES satellites revealed unprecedented features of tornadic storms and hurricanes. Completion of a four year Atlas of Antarctic sea ice from Nimbus-5 ESMR has opened the door to studies of the role of sea ice in the climate system. Aircraft experiments have demonstrated the feasibility of measuring directional ocean wave spectra from space using a short pulse radar.

### Climate Information

In 1981, a four-year (1972-1976) sea ice concentration data set for the Antartic was completed. The Atlas will be published in early 1982. These data were important to studies of climatic effects related to sea-ice/atmosphere interactions and as an index relative to hemispheric and global climate change and variability.

The compilation of the first year of global ozone data, both total and vertical profiles, from the NIMBUS-7 satellite remote sensing instrumentation was completed in 1981. The archiving of more precise vertical profiles of stratospheric ozone from the improved AEM-SAGE satellite sensor has begun this year as well. These data are a significant addition to the Nim-

bus-5 ozone data set recently made available to the user community. Ozone measurements and climatology are particularly important at this time because of the ozone depletion question.

A two year data set of stratospheric aerosols in the polar regions, based on the findings of the Nimbus-7 aerosol sensor, was completed in 1981. Significant data are being added by the AEM-SAGE satellite, which detects, on the average, two volcanic eruptions a year and has the ability to track particulates injected into the stratosphere and to determine the mass loading. Remotely sensed data gathered in connection with the Mt. St. Helens eruption including NASA U-2 aircraft sampling data is outlined in the NASA workshop report "Mt. St. Helens Eruptions of 1980; Atmospheric Effects and Potential Climate Impact," published in 1981. Stratospheric aerosol information is very valuable in cause and effect studies concerning atmospheric chemistry and atmospheric heating or cooling that are believed to result from increases in atmospheric $CO_2$.

Development of the data retrieval algorithm for extracting Earth radiation budget information from Nimbus-7 was completed and verified in 1981. Production of data sets will begin in early 1982. Development of effective algorithms were difficult for the earlier Nimbus-6 Earth radiation measurements because the scanning part of the instrument did not function long enough. Now, with the Nimbus-7 algorithm, work has begun this year to extend the Earth radiation budget data set back to the beginning of Nimbus-6 in 1975. The Earth's radiation budget is a key element, both globally and regionally, in climate research studies, since it can be used in analysis of Earth energetics and heat transport, analysis of regional climate conditions for assessing potential drought, and similar applications.

A solar radiation data set for the top of the atmosphere (solar constant) is presently being archived. This data set begins with rocket data in 1975 and continuing with Nimbus and Solar Maximum Mission data.

A major effort was begun in 1981 for the development of a systematic global cloud data base from operational satellite observation for the period 1983-1988. In this multi-agency and international project, NASA is a key participant and provides the manager for the project. The International Satellite Cloud Climatology Project (ISCCP) Plan was completed in 1981. For experimental purposes, a global cloud data set for the months of January and July of 1977, derived from the operational satellite scanning radiometer, was completed in 1981, and data for the full year of 1977 will be archived in 1982. Also, a regional ($45^{o}S$ - $45^{o}N$;$30^{o}W$ - $120^{o}W$) experimental cloud data set was completed this year for the month of November 1978 using geosynchronous satellite data. Highly specialized cloud physical data were obtained with the NASA WB-57 aircraft during May-June 1981 while participating in the multi-institutional Cooperative Convective Precipitation Experiment (CCOPE) in the Western U.S. These data have particular relevance to cloud radiation and classification studies. In a joint NOAA/NASA effort, the first half of a 3-year Nimbus-7 cloud cover data set (October, 1978 - June, 1980) was completed and will be available for distribution in early 1982. Cloud observations and cloud studies are interrelated with Earth radiation budget measurements and studies. Cloud data is also important for climate fluctuation and hydrological cycle studies.

An updated Nimbus-5 global microwave brightness temperature data set for the period 1973-1977 was completed in 1981. This unique data set can be applied to ocean precipitation studies and polar ice studies.

Seasat Data sets of approximately 100 days (June 26 - October 10, 1978) for the following parameters were completed in 1981:

- Ocean wind stress,
- Ocean wind vectors,
- Ocean wave height and spectra,
- Sea surface temperature, and
- Water vapor over the ocean.

Although major satellite data sets are available through the National Space Science Data Center (NSSDC), the first phase of a Pilot Climate Data Base Management System (PCDBMS) was completed in 1981 to provide specific climate data services to NASA and NASA-supported researchers. Over 20 climate-related data sets are cataloged in the system that now includes the GARP Global Weather Experiment data sets. Planning is underway to interface this facility, centered around a VAX-11/780 computer, with the NOAA Climate Information Clearinghouse function of the National Environment Data Referral System for cooperative exchange of information and as a mechanism for making NASA's climate information available to the user community at large.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. O. Thiele
Telephone: (301) 344-7006

*The improvement in forecasting skill from FGGE satellite data.*

## Global Weather And Climate

The First Global Atmospheric Research Program (GARP) Global Experiment, completed in 1979, has provided the most extensive atmospheric data ever gathered. The Modeling and Simulation Facility has developed the Goddard Laboratory for Atmospheric Sciences (GLAS) Analysis/Forecast system to improve utilization of satellite data in weather prediction. A comprehensive satellite data impact study has been completed for a two-month winter period, and the results indicate that satellite data (temperature soundings and cloud tracked winds) had a beneficial impact on the accuracy of numerical weather forecasts. This improvement is larger beyond one or two days and is reflected in the fact that when satellite data are utilized, there is a two-fold increase in the number of forecasts that remain skillful after 5 days.

A further study using GARP data showed that a satellite system without use of the rawinsonde network was better than a rawinsonde system without satellite data in the southern hemisphere, but somewhat poorer in the northern hemisphere. The Analysis/Forecast system is currently being used to determine the relative importance of the individual components of the First GARP Global Experiment (FGGE) satellite observing system (i.e. infra-red and microwave temperature soundings, different geostationary cloud tracked wind systems, drifting buoy data collected from space, etc.) Another application is the development of a simulation system for studying the potential impact of future observing systems such as advanced infrared and microwave sounders, scatterometer observing systems, lidar systems, etc. The simulation system will be calibrated using FGGE data.

Several experiments using FGGE data have been performed to determine the accuracy of tropical forecasting and the impact of improved tropical observations upon extratropical forecasting. It has been found that under certain dynamic conditions, tropical data can have a very large impact on extratropical forecasts within 3 or 4 days. Analysis of tropical forecast shows large systematic errors after only one or two days. This points out the need to improve the parameterization of physical processes such as cumulus convection which are essential in maintaining quasi-stationary tropical circulations. On the other hand the forecasts retain some skill in predicting transient tropical features for about 3 days, especially when the FGGE special observing systems are included in the initial conditions.

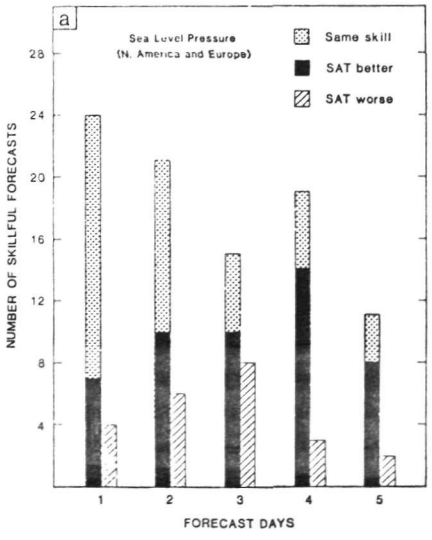
A detailed study of the large amplitude stationary Rossby waves discovered in the southern hemisphere has been completed. It has been found that the waves are not forced by the Andes as it was originally thought, but by enhanced tropical heating which leaks into the extratropics.

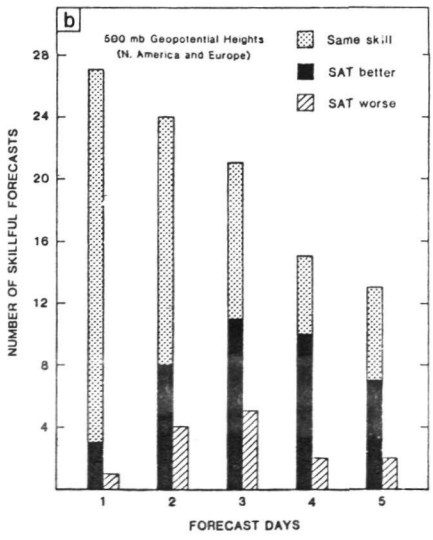
The GLAS Analysis/Forecast system has also been modified to allow the use of scatterometer surface winds. New de-aliasing procedures have been developed, using the McIdas system and a variational analysis method. These methods are being included in the objective analysis scheme in order to produce one month of high quality dealiased SEASAT-A scatterometer wind data. The impact of these winds on numerical weather prediction will be studied with this data set.

A processing system to obtain temperature soundings from TIROS-N radiances has been completed. It is based on the radiative transfer equation, and provides atmospheric temperature profiles, as well as sea and land surface temperatures and cloud heights and amounts. It provides researchers with the ability to directly process satellite radiances.

Extensive studies have been completed which established the physical basis of the prediction of monthly, seasonal mean climates, by using simulated anomalies of sea surface temperature and other data as observed by satellites. In support of this effort, an improved climate model has been developed to simulate the seasonal cycle. Preliminary tests show that the model is capable of very realistic simulations of summer and winter circulation regimes.

A GLAS general circulation model has been run with two assumed extreme global conditions of soil moisture: dry and saturated. The differences in the simulated atmospheric



circulations are enormous. The study shows that evaporation is an important factor in determining the rainfall over land. It strongly suggests that global observations of soil moisture can provide potential predictability for monthly and seasonal anomalies in the atmosphere.

The first complete global monthly climatological data set of ground wetness was compiled using observations of precipitation and surface temperature. These results are of great importance, since simulation studies have shown the sensitivity of the atmospheric circulation to ground wetness anomalies. In particular, simulation experiments were used to show that regions of anomalously high surface brightness are favored locations for drought. This supports the idea that albedo provides a positive feedback mechanism for desert formation.

It has also been shown that a simple nonlinear barotropic model with realistic topography can explain about 60% of all the actual blocking events that occurred during the 15 years between 1963 and 1977.

The turbulence-radiation model has been used to demonstrate that stratocumulus cloud decks are very sensitive to the depth of the radiatively cooled layer near cloud top. This suggests that improved radiation parameterizations are needed to allow more realistic simulations of global cloudiness and its impact on climate.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. M. Halem
Telephone: (301) 344-7482



**Oceans And Ice**

Studies with the GSFC's upper ocean model provided new insights into the generation and stability of tropical flows, the tropical heat budget, and the role of upwelling and horizontal advection in maintaining the equatorial Sea Surface Temperature (SST) distribution. The dynamics of the upper ocean are significantly modified by masking effects in the mixed layer, (e.g. Kelvin waves), and an understanding of their relationships is crucial to an informed monitoring program for equatorial SST.

The ocean color program has focused its emphasis on the upwelling dynamics and associated bioproductivity of the Gulf Stream front along the Florida-Georgia continental shelf. The studies have incorporated data from the U-2 Ocean Color Scanner, the Thematic Mapper Simulator, and Nimbus-7 Coastal Zone Color Scanner. Since the upwellings are produced by several different mechanisms and occur on a variety of space and time scales, it is difficult to locate and adequately sample upwelling events using traditional ship and mooring techniques. The thermal and visible imagery have provided an instantaneous view of sea surface temperature and surface chlorophyll concentration, both of which provide information necessary in determining which mechanisms are at work for the particular situations observed. Analysis of data taken during 1979 and 1980 has shown that, contrary to earlier assessments, high productivity does occur regularly on the outer continental shelf. A third study that included field measurements of biological, radiometric, and hydrographic parameters, was conducted in 1981. The final results should clarify questions regarding ocean color and its dependence on chlorophyll concentration, and also should identify additional mechanisms responsible for shelf break upwellings.

Research carried out this past year indicates that it is possible to make quantitatively useful measurements of the directional wave-energy spectrum on a global scale using relatively simple satellite-borne microwave radars. In the measurement approach being considered, the radar would operate in a conical scan mode near vertical incidence, where the backscatter from the surface occurs by specular reflections from individual wave facets. Using a simple first-order scattering model, the directional energy spectrum can be easily recovered. With relatively simple onboard processing, the data rates can be made quite low so that global coverage is feasible. The technique has been demonstrated at aircraft altitudes (10km) and has been shown to yield rather accurate estimates of the directional energy spectrum. The technique is particularly attractive since it can be implemented using existing hardware such as the SEASAT Altimeter, so that the cost of development is low.

In the area of sea ice research, detailed analyses of Sea Surface Temperature (SST) and sea ice properties from the multispectral, dual-polarized radiances obtained on board Nimbus-7 by the Scanning Multichannel Microwave Radiometer (SMMR-7) were conducted. This year's activities resulted in significant improvements in the geophysical parameter retrieval algorithms used for these purposes. With regard to SST, it has been demonstrated that point-by-point comparisons of SST's inferred from SMMR-7 and two independent surface observation data sets have indicated the SMMR-7 retrievals have an uncertainty of $1^{o}K$, which was about the same as the uncertainty in each of the independent surface observation sets. The uncertainty drops to about $0.7^{o}K$ when the SMMR-7 and surface observations are spatially averaged over 200km cells and temporally averaged over intervals of a week to a month.

Earlier determinations of sea ice concentration from single-channel observations such as those from the Nimbus-5 ESMR have been significantly improved with the use of the multispectral radiances available from the SMMR. Central to the success of the new retrievals has been the decoupling of the physical temperature of the radiator from its emissivity through the expedient of utilizing ratios of the multispectral radiances. In addition to a predicted threefold improvement in accuracy in sea ice concentration retrievals, compared to those from Electronically Scanning Microwave Radiometer (ESMR), the new multispectral algorithm also yields information on multiyear sea ice distribution, as well as the physical temperature of the sea ice. The new algorithm will find widespread use in weather and climate studies, resource extraction and safety studies, and planning for future international, inter-agency field studies in the cryosphere, such as the Marginal Ice Zone Experiments (MIZEX) planned for 1983-86.

As a part of the effort to understand the influence of atmospheric circulation on southern ocean sea ice cover, two studies comparing sea ice data with atmospheric data were undertaken. The sea ice data were three-day averages derived from the ESMR on Nimbus-5. The atmospheric data were 12-hourly pressure and temperature fields compiled by the Australian Bureau of Meteorology. Both studies examined the large-scale coupling between ice and atmosphere, the first covering time scales ranging from weeks to months over the 1974 annual cycle, and the second dealing with interannual variations in monthly means for the years 1973 through 1975.

A comparison of sea ice concentrations derived from near simultaneous images from the ESMR and LANDSAT revealed a basic shortcoming in the visual interpretation method currently employed for evaluating the percentage of ice cover from the visible imagery. The LANDSAT images have much better resolution than those of ESMR. However, because of the existence of very narrow leads, small ice floes, and thin ice, the visual interpretation of LANDSAT images usually overestimates the ice concentration within the ice pack. When a proportional classification scheme similar to that used for the ESMR brightness temperature data was employed, the ice concentration calculated from LANDSAT images was found to be consistent with those from ESMR within about 12%, which is the estimated accuracy of the latter measurement.

Satellite data indicate that the calving terminus of Columbia Glacier has continued to retreat in excellent agreement with numerical model predictions, made in June 1980, of a catastrophic retreat in late 1983. A brief terminus advance in August 1980 has been compensated for by a large retreat in August 1981, putting the overall retreat "back on schedule." The increased rate of calving has forced periodic cessation of tanker traffic transporting oil from the southern terminus of the Alaska pipeline. During the catastrophic phase of retreat, the iceberg production rate is expected to rise markedly, causing prolonged halts to all shipping near the glacier. If tanker traffic were to be stopped for as little as one week, the storage capacity at the tanker port would be exceeded, and extremely expensive measures would be required to prevent the oil in the pipeline from freezing.

Studies are being organized to look at scientific missions which could be conducted by flying Scatterometer and Coastal Zone Color Scanner (CZCS) instruments on TIROS-N or other operational spacecraft. The scatterometer would provide data for scientific sea surface stress studies. The CZCS images would contribute to ocean productivity research. Scientific Working Groups to define requirements are getting under way.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. D. B. Rao
Telephone: (301) 344-4718

**Ocean-Atmosphere Coupling**

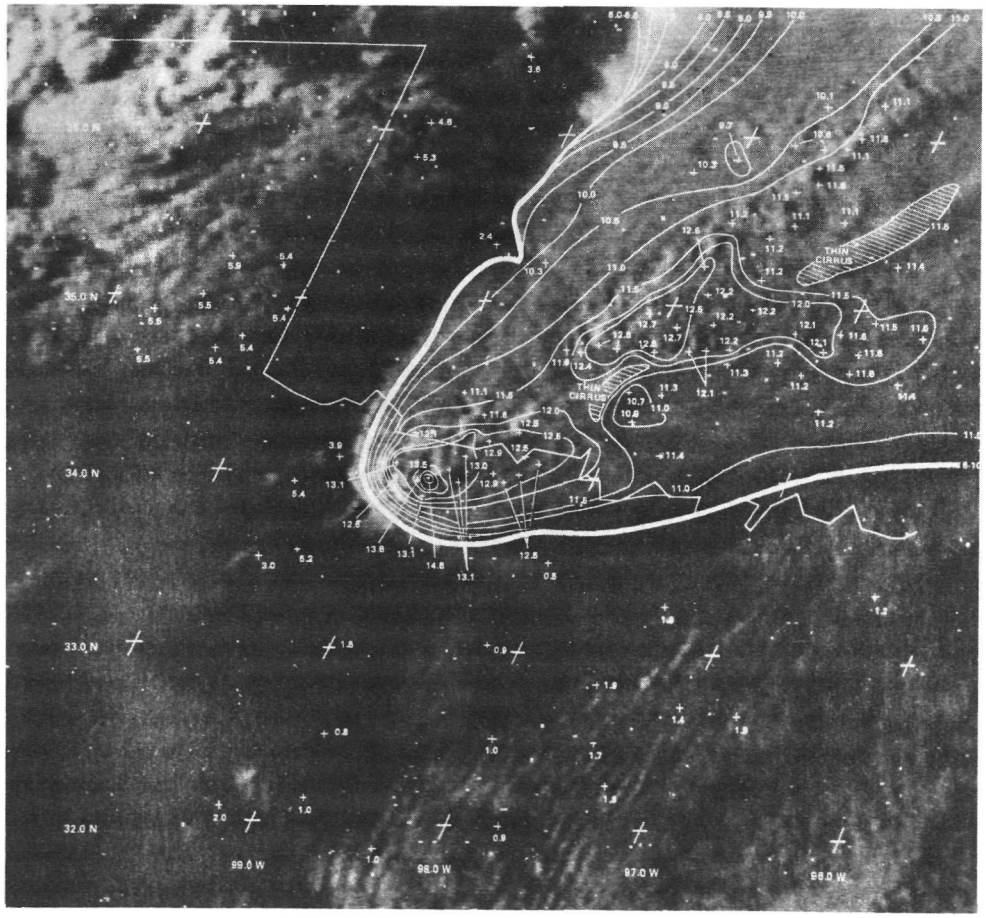
Numerical models of the coupled ocean-atmosphere system are being developed to study short term climate variability of the time scales of Southern Oscillation/El Niño. ( ~ 3-5 years). Preliminary experiments with these models suggested feedback mechanisms involving atmospheric Hadley and Walker-type circulations and upper ocean and mixed layer dynamics. It has been shown that the period of natural oscillations in a closed equatorial basic can be significantly affected by the presence of air-sea coupling. Experiments are being planned to further study the role of air-sea interaction in the observed teleconnection patterns of the tropical and midlatitude ocean-atmosphere system. Results of these coupled model experiments will hopefully shed light on the recent observations of coherent changes in the ocean and the atmosphere during different phases of the Southern Oscillation/ El Niño.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

## Severe Storms

Meteorological uses of satellite observations have been important to meteorological predictions since the first TIROS satellite was launched over 20 years ago on April 1, 1960. Earlier usage of satellite observations concentrated on larger (synoptic) scale features such as hurricanes and frontal systems identified by their characteristic cloud patterns and the intervening fair weather regions. With the advantage of satellite observations, global observations (previously impractical due to cost of observing over vast ocean and uninhabited regions) became a reality. With the increasing space and time resolution provided by improved instrumentation, use of a wide variety of wavelengths for observing, and development of geosynchronous satellites, even extensive sub-synoptic or mesoscale meteorological observations became practical. Previously, such smaller scale observations were accomplished only at great expense over very limited areas for very limited time periods and were very useful primarily for research purposes. At present, there is an ever increasing interest in studying meteorological observations from satellites, aircrafts, balloons, and ground facilities in order to develop a most cost-effective combined observation system to support predictions which are most useful to our society. Severe storms are of primary interest to our society since they present such a great potential for death and property damage. These storms are most frequently a mesoscale occurrence embedded in, and influenced by, a synoptic scale atmospheric environment. Conversely, the small-scale storm is also often an important influence on this larger scale environment.

Progress in severe storm prediction is best carried out by an interactive process of parameter selection (based upon current physical knowledge), observation, analysis, research, and modeling. These processes are carried out concurrently and must be interrelated frequently. If an optimal observing system of useful parameters is applied to a model which optimally incorporates our current physical knowledge, the result should be the best forecast possible, given our present state of knowledge. Goddard research in severe storms is directed toward developing a better physical understanding of severe storm mechanisms in order to improve our storm model observation techniques, and parameter selection. Two powerful tools are routinely used in our research: 1) an interactive computer display facility is available to map, overlay, compare, and otherwise




*Cloud top stereographic topography from spacecraft: This image showing cloud topography contours was prepared from satellite stereographic data. Simultaneous data were taken from two geosynchronous satellites, one stationed south of the U.S. east coast. These geostationary satellites stationed near the equator at about 36,000 km altitude viewed this severe storm system over the Oklahoma-Texas border region. The high cloud topography (14.6 km) in the center of the illustration is associated with the well known Withita Falls tornado of April 10, 1979, which occured about 5 minutes after the photograph. The tornado caused 2 deaths and property damage in the millions of dollars. Tornados also occured within the previous hour, associated with the other maximum height contour of 12.6 km. The higher thin cirrus areas prevented stereo measurements of the cumuliform cloud top in those areas. The scattered white specks are data drop-outs.*

analyze data from a variety of sources; and 2) models uniquely developed to accommodate satellite data and to include mesoscale atmospheric processes are being developed in order to verify research results, study parameters for observation, and to facilitate utilization of satellite data into the prediction process.

In our research, satellite data (visible imagery data, IR imagery data, microwave sounding, and stereo observations) are combined in a variety of ways with each other and with non-satellite data to verify and improve our parameter selections, parameter definitions, and related algorithms; and to learn more about storm physics for use in model improvement. Recent significant accomplishments include the first stereo observations of a tropical storm, hurricane Frederic near Mobile, Alabama, of September 12, 1979. These were made at 7.5 minute intervals from 2 geosynchronous satellites and permitted the preparation of a number of cloud topography analyses. From these analyses, measurements have been derived which include 1) vertical cloud top growth rates; 2) changes in area of hurricane Central Dense Overcast (CDO); 3) hurricane rain band propagation; 4) divergence and vertical velocity; and 5) CDO slope which may be related to the tropopause surface. Similar stereo observations have also been made of severe thunderstorm and tornado bearing cloud systems in the midwestern states and are being studied. The stereo-height assignments of cloud temperatures have been reviewed and show promise for determining tropical storm intensity (maximum tangential wind).

The advanced microwave sounder (VAS) data from the GOES satellite permits sounding in cloudy, as well as cloud-free regions. Studies are underway to determine the optimal use (time and space resolution) for these data and to determine the impact of these data on the results produced by predictive models. In addition to these satellite stereo and satellite sounding accomplishments, some other recent findings are noted.

- Upper and lower jet interactions have been found to be important in cyclogenesis.
- A satellite-enhanced humidity analysis used in modeling initializations of extratropical cyclones has been demonstrated to improve rainfall prediction accuracy.
- Satellite-derived rainfall rate estimates used in modeling initializations of tropical cyclones have been demonstrated to improve storm intensity predictions.
- Satellite-derived wind fields have been used to monitor, and in some cases, predict tropical cyclogenesis.
- Cloud top IR temperature within 222 km of a tropical cyclone center has been found to be closely related to wind intensity 33 hours later.
- Cloud top IR temperature patterns have been used to make 12 to 72 hour predictions of tropical storm motion.
- Minimum Cloud Top Temperature (CTT) which rapidly cools then warms shows promise for an indicator of tornadoes.
- Small changes in CTT observed above the tropopause show potential for indicating a maximum rain area.
- An automatic-objective technique using an N-channel radiometer has been demonstrated to successfully classify ground and atmospheric features such as cloud-types, ground surface types, and moisture patterns.
- Satellite soil moisture observations used as supplemental model input, have been shown to improve predictions.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Joanne Simpson
Telephone: (301) 344-8569

**Optical Sensor Research**

Significant improvements in the measurement of basic atmospheric parameters are required for improved weather forecasting, the prediction of climate change, and increased understanding of atmospheric processes. GSFC is conducting advanced research on a number of new remote sensing techniques. These include the development of new lidar techniques for the measurement of atmospheric pressure, temperature, carbon dioxide, and cloud properties as well as conducting supporting high resolution spectroscopic measurements.

There is a requirement for remote measurements of the atmospheric pressure field and for improved measurements of the atmospheric temperature profile. Although pressure is one of the fundamental atmospheric state variables, there are no current remote sensing techniques for measurement of this pressure field. Thus, important forecasting tools such as maps of surface pressure and 500 mb 5km height contours must be produced either by in situ measurement or by indirect methods. The development

and application of temperature sounders to improve the understanding and forecasting of weather is a major thrust of the NOAA and NASA Meteorological Programs. The capabilities of current passive sounders have not been able to meet the required accuracy level of $1^{o}C$, and the development of new techniques, such as lidar sounders using pulsed lasers, is needed.

New lidar techniques for the measurement of atmospheric pressure profiles, surface pressure, and temperature profiles have been developed at the Goddard Space Flight Center. Field measurements using continuous wave lasers have demonstrated measurements of surface pressure to accuracies of 1.5 mb and temperature to accuracies of $0.6^{o}C$. A pulsed laser experiment for measuring vertical profiles of pressure and temperature from ground-based and aircraft platforms has been constructed and initial measurements of atmospheric backscatter have been made. A tunable high energy solid state laser, Alexandrite, has also been successfully tested as part of this experiment.

The feasibility of lidar measurements of the distribution of atmospheric carbon dioxide has also been investigated. In order to understand how much of the excess $CO_2$ is recycled by vegetation and by solution in the cold sea surface of polar areas and in regions of upwellings, $CO_2$ measurements are required diurnally.

During the past year, analysis of data acquired by an airborne Cloud Lidar System (CLS) has produced highly successful results. The development and operation of the CLS instrument is the first time lidar has been used as an independent automated sensor. Data acquired during flights on the WB-57F research aircraft have produced high resolution measurements of cloud top height, scattering coefficients, and depolarization. Passive visible and infrared measurements were also obtained during the flights which provide a unique study of the clouds radiative characteristics. During the past year, modifications to the CLS were also incorporated to give improved resolution and coverage and dual wavelength capability. The improved CLS was flown in cooperation with the CCOPE convective storm experiment. Studies with these experimental data will further develop the utility of lidar remote sensing.

Goddard researchers have also developed a laboratory which has the capability to measure molecular line parameters with a unique, cold optics, 3-meter focal length grating spectrometer which operates from 1 to 30 $\mu m$ and a turnable diode laser spectrometer. We have successfully obtained the first spectra from the cold optics instrument. Selected measurements of CO, $CH_4$, and OCS have been made in both the 2 and 10 $\mu m$ (1000 $cm^{-1}$) spectral regions. A resolution better than 0.017 $cm^{-1}$ has been demonstrated in both regions. This is the highest resolution ever obtained beyond 5 $\mu m$ with a grating spectrometer and shows, in part, the signal-to-noise enhancement obtainable with the use of cold optics.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. C. Laurence Korb
Telephone: (301) 344-6233

**Microwave Sensor Research**

Theoretical investigations performed during the last fiscal year included the mechanisms of radiation from lightning, relativistically covariant scattering from moving hydrometeors, and interferometric synthesis of a large aperture from multiple smaller apertures. In a program to develop rain and water vapor mapping systems, the advanced microwave moisture sounder (AMMS), a multifrequency microwave radiometer, was flown on the NASA WB-57 high altitude aircraft in conjunction with the Cooperative Convective Precipitation Experiment (CCOPE). Similarly, truck-mounted radiometers were used to investigate the microwave properties of snow and of agricultural fields with varying soil moisture and vegetation cover.

Nearly 3 years of data from the Scanning Multichannel Microwave Radiometer (SMMR) are now in hand. Goddard researchers are deeply involved in the effort to extract ocean surface and marine atmospheric parameters from these data. This effort has resulted in sea surface temperature retrievals with better than $1^{o}C$ accuracy.

Sponsor: Office of Space and Terrestrial Applications
Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Dr. T. T. Wilheit
Telephone: (301) 344-5105

**Cloud Radiation Experiment**

As part of the Climate Research RTOP, an experimental effort has been underway for the past two years to better understand the radiative properties of extended cloudiness and its effect on the Earth's radiation budget. The experimental effort involved the development of a scanning radiometer and its application. Taking advantage of a special field experiment opportunity, the Multispectral Cloud Radiometer (MCR) was used in the Cooperative Convective Precipitation Experiment (CCOPE) in May and June, 1981. CCOPE was a multi-institutional research project conducted in southeastern Montana during late spring and summer 1981. The

experiment involved 17 aircraft making observations above and in clouds, in addition to ground based meteorological and radar observations. The MCR was carried on board the NASA WB-57F complemented by a scanning microwave radiometer and a cloud lidar system. The GSFC payload was flown successfully on all eight of the flights scheduled during the early phase of CCOPE. Analysis of previous data taken with the MCR indicates its capability to quantitatively determine: cloud optical thickness, cloud top altitude, volume scattering coefficient, phase, particle size and cloud top temperature. Initial analysis of the MCR data taken during CCOPE indicates it is of high radiometric quality. Quantitative analysis of the data will continue through detailed algorithm development and comparison with the extensive in situ measurements made in CCOPE. These comparisons will serve to validate the remote sensing techniques. In addition to these studies of the remote sensing techniques, the data will provide a basis to improve our understanding of the cloud microphysical and macrophysical structure and their relationship to the evolution of precipitating convective clouds.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

**Aerosol Research**

Aerosols are critical in the formation of clouds and therefore for climate. Methods are being developed to monitor anthropogenic aerosols with satellite observations. The Visible Infrared Spin Scan Radiometer (VISSR) mounted on geostationary satellites measures the radiance of sunlight scattered from the United States every half hour with a resolution of 2 km. Unfortunately, these radiances are not calibrated. A calibration procedure to establish precision, but not absolute accuracy, was developed by comparing measured and computed radiances of cloudless ocean areas where the aerosol content is low.

Aerosols also degrade the quality of satellite observations of the Earth's resources by altering their spectral signatures and by blurring and reducing contrasts in satellite images. The blurring effect depends not only on the optical character of the atmosphere, but also the surface reflectance distribution. Appropriate radiative transfer models have been developed to account for surface inhomogeneities. Each point of the surface can be considered as a virtual source of light. If a dark lake of a few hundred meters is surrounded by bright land, for example, the land illuminates the atmosphere above the lake, and the atmosphere there is brighter than if the lake were 10 km wide. The phenomena of transferring light from bright areas to nearby dark areas is called the adjacency effect. The adjacency effect was measured by the Landsat MSS where the bright African desert meets the dark Atlantic Ocean. Aircraft experiments to measure the adjacency effect are planned.

The adjacency effect on the classification of rural areas by the MSS was simulated by computing the radiances that would be measured by the MSS. The classification accuracy depends on the number of surface types, their size and distribution, and on the optical characteristics of the atmosphere. Under reasonable conditions though, a forest 1 km in diameter surrounded by bare soil was classified as wheat stubble. As another example, a 100m pond in a soybean field was classified as bog, even after atmospheric corrections were made that did not account for the adjacency effect. Both theoretical and experimental studies of this important effect are continuing.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

**Climate Fluctuation Research**

The characteristic space and time scales for cloud fluctuations have been estimated and mapped over the Pacific Ocean using data from NOAA operational polar orbiting satellites. These results show time and space scales about half the size of those normally associated with atmospheric disturbances. The results will be useful in determining cloud parameterizations for general circulation models. This statistical analysis is one of several underway at present. More theoretical studies include the estimation of sampling errors associated with characteristic climatological variability patterns and an explanation for why so many zonally averaged climate parameters are more variable in polar regions.

The energy balance models continue to be of interest because of their tractability and the insight gained from the study of their solutions. In one study involving a homogeneous planetary surface with atmospheric eddies, simulated by random noise analytical solutions, were found and applied to the problem of climate predictability. The conclusion for the idealized model suggest that coupling atmospheric conditions to oceanic mixed layer models might lead to improved climate prediction.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

### Marine Boundary Layer Studies

Based upon the measurements made by Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) data, microwave remote sensing of water vapor in the atmosphere over global oceans has been demonstrated to be extremely valuable. The accuracy of the satellite sensed precipitable water vapor in the atmosphere was shown to be 0.25 $g/cm^2$. With this accuracy it was shown that it is possible to map several key features associated with warm and cold ocean currents, and the intertropical convergence zones. Since the water vapor in the atmosphere is controlled by the sea surface temperature and the dynamical state of the lower troposphere, sensing the water vapor over the ocean on a monthly basis from year to year would make an important contribution in revealing significant changes in the climate.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

### FGGE/MONEX Study

Radiation budget data from TIROS-N polar orbiting satellites in conjunction with meteorological data from FGGE/MONEX are used to study synoptic and planetary scale interactions over the tropics and midlatitudes during northern winter and summer monsoon periods (FGGE/SOP-I, II). At present, the study focuses on the mechanisms leading to the onset of severe monsoon cold air outbreaks (cold surges) over East Asia and their effect on tropical convection. The intensity of these cold surges and that of the associated tropical convection as inferred from outgoing long wave and albedo measurements are compared to those deduced from wind, temperature and geopotential measurements. A scenerio of the onset and subsequent influences of cold surges involving triggering due to midlatitude wave disturbances and positive feedback from tropical convection, is now being established. This will lead to a better forecast of the cold surge onset. The study will also provide a basis for the study of interannual variability of the large scale tropical circulations.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. A. Arking
Telephone: (301) 344-7208

## UPPER ATMOSPHERE RESEARCH

GSFC's activities in upper atmospheric research include experimental and theoretical programs devoted to expanding our understanding of the physical, dynamic and chemical processes which determine the state of the stratosphere and mesosphere. Experimental efforts include the balloonborne lidar system for measurement of the hydroxyl radical (OH), the Solar Backscatter Ultraviolet Experiment on Nimbus-7 for global monitoring of stratospheric ozone, and rocket flights of an ultraviolet spectrometer to measure atmospheric attenuation of the solar irradiance. Theoretical efforts include interpretation of measurements utilizing sophisticated models of photochemistry and radiative transfer and the prediction of future changes in upper atmospheric composition due to anthropogenic effects and solar activity. A significant new theoretical effort is under way to study the coupling among the chemical, radiative, and dynamic processes in the upper atmosphere. One of the goals of this effort will be to gain the ability to evaluate chemical perturbations of the atmosphere with an accurate representation of atmospheric dynamics.

The Solar Backscatter Ultraviolet Experiment, placed in orbit on the Nimbus-7 satellite, continues to operate normally, and data analysis are proceeding. This instrument observes the backscattered Earth's radiance in ultraviolet, from which profiles of ozone are derived over the altitude range 25 to 55 km. The instrument also conducts periodic measurements of the solar spectral irradiance and total ozone. These complement data from the accompanying Total Ozone Monitoring System, which provides global scale maps with high temporal and horizontal resolution.

Data from the Nimbus 7 Solar Backscatter Ultraviolet Experiment has been combined with data from the Nimbus 4 Backscatter Ultraviolet Experiment taken from 1970 to 1980 to search for possible secular changes in the ozone distribution. A continuing decrease has been found. This decrease is centered about an altitude of 40 km where destruction of ozone due to release of chlorofluorocarbons has been predicted to be highest. The interpretation of these observations and the assignment of cause is confounded by the possible instrument drift and by the many other processes which could cause change, especially those related to the 11-year solar cycle. Studies are currently underway at GSFC to examine the possible causes of solar cycle variations in stratospheric ozone and to relate them to the observed variations from the Nimbus satellites.

The Nimbus observations of the solar ultraviolet flux, combined with previous observations, are being utilized to attempt to delineate the magnitude and time scales of solar variability in the 1800 to 3000A wavelength region. Variations with the 27-day solar rotation period are well

established.

The Nimbus satellites have also provided backscattered ultraviolet measurements of ozone during short-lived events such as solar proton events. The atmospheric effects of these events are caused by high-energy protons associated with solar flares. Previous studies have demonstrated that the decrease in upper stratospheric ozone observed after the major August 1972 event can be explained by the catalytic destruction of ozone by nitrogen oxides created in the slowing-down of the protons. Work recently completed at GSFC has utilized several smaller solar proton events to examine the shorter term effects expected because of the hydrogen oxides created by the protons.

Data from the Total Ozone Monitoring System has been used in studies to determine stratospheric fronts, the position of the jet streams, and the altitude of the tropopause, and for high ozone avoidance for commercial aircraft. A real-time test was successfully performed this Spring, in cooperation with Northwest Airlines, of the application of the data to airline flight planning.

Recent modeling studies at GSFC have shown that the sources of upper atmospheric nitric oxide associated with sporadic solar particle events can be significant in comparison with the background sources at high latitudes in years of high solar activity. This implies a variability in the odd nitrogen content of the stratosphere and mesosphere with the solar cycle which may be observable in a long-term data set. These have implications back on the observed ozone variability and its interpretation in relation to solar cycle effects. These studies combined with the solar ultraviolet variability studies and ozone variability studies are part of a broad attack on the problem of understanding stratospheric ozone and the mechanisms responsible for its maintenance.

GSFC organized and directed a workshop to summarize the status of knowledge concerning the upper atmosphere and its possible perturbation through human activities. Approximately 100 scientists contributed to the workshop, which will result in a workshop report to be published early in 1982, under the joint sponsorship of the World Meteorological Organization and three U. S. agencies, NASA, NOAA, and FAA. The following are four major findings of the report concerning ozone perturbations: 1) smaller computed ozone change for continued release of chlorofluorocarbons at present rates, 2) increased computed ozone sensitivity to nitrogen oxide release, 3) greater realization of the importance of considering the combined effects of all possible influences on stratospheric ozone, and 4) an observed slight increase in total ozone throughout the 1970's with statistical error bars that include no change. This last finding is consistent with the predicted combined effect of chlorofluorocarbons, subsonic aircraft emissions, and carbon dioxide increase.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Richard S. Stolarski
Dr. Robert D. Hudson
Telephone: (301) 344-5485/344-6358

### Upper Atmosphere Research Satellites (UARS)

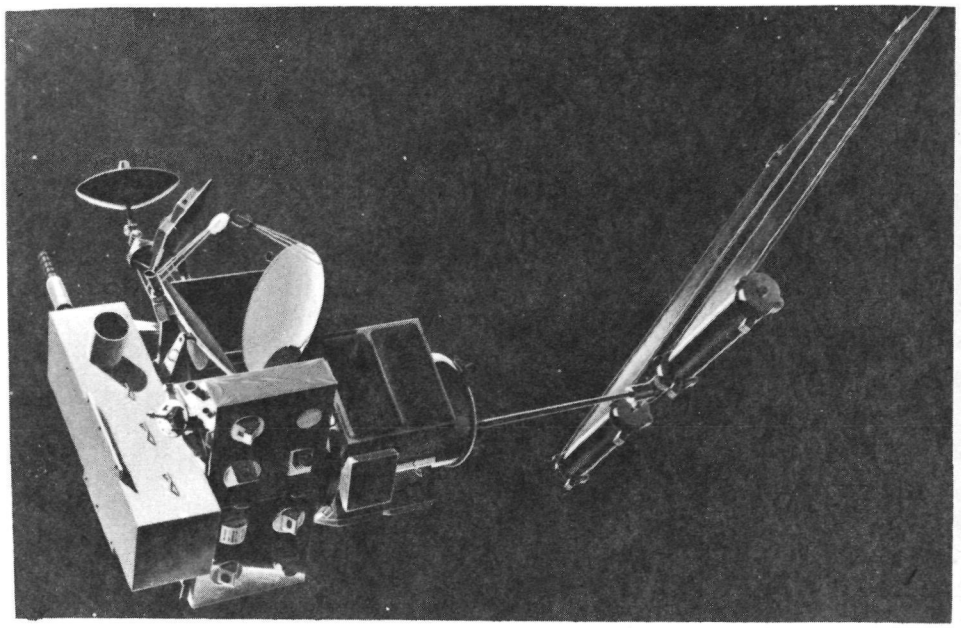
There has been increasing concern in recent years about the sensitivity of the atmosphere to external influences associated with natural phenomena and changes arising from by-products of various human activities. Specific threats to the stratosphere have been postulated in the release of chlorofluoromethanes (freons) in the troposphere and of nitric oxide emitted from high-altitude aircraft. Several current satellite measurements in the stratosphere and mesosphere address some of the chemical processes associated with these concerns, but these measurements generally represent different times and geophysical conditions so that the relationship between them is tenuous at best. The Upper Atmosphere Research Satellites (UARS) project will bring together all the appropriate measurements in the same time frame in a coordinated and comprehensive research program designed to greatly further our understanding of the basic physical and chemical processes that control this vital region of the Earth's environment.

The UARS program consists of two free-flying satellites, launched one year apart beginning in the fall of 1988, with a nominal measurement lifetime for each of eighteen months. The first flight will allow measurements over most of the Earth and in addition will permit studies of local time effects (dawn-dusk, night-day, etc.) in the upper atmosphere. The second flight will provide measurements over the entire globe, including effects of auroral energy inputs to the atmosphere at high latitudes. The six months of temporal overlap of measurements from the two satellites will permit intensive study during the winter season in the Northern Hemisphere, a period of particularly interesting meteorological activity.

The majority of the 9 to 11 instruments on each spacecraft perform their mearsurements by remotely sensing atmospheric radiation parameters from the ultraviolet to the infrared. These, in turn, will yield altitude profiles of atmospheric temperature, winds, and chemical species of interest and a quantitative assessment of the solar spectral energy incident on the atmosphere. To ensure prompt processing and analysis of the scientific data from the UARS program a Science Team has been formed, consisting of

the individual scientists responsible for each instrument and 10 theoretical scientists who will participate in the geophysical interpretation of the data. The Science Team members will be aided by a data handling system tailored specifically to their needs, consisting of a central facility to collect and process the data and remote terminals at the scientists' laboratories, complete with mini-computers on which they can perform their own extensive analyses, using all the data obtained.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. Nelson W. Spencer
Dr. Carl A. Reber
Telephone: (301) 344-5001/344-6534



*Upper Atmosphere Research Satellite.*

### Environmental Quality

The GSFC program in environmental quality includes both photochemical modeling studies and measurements of meteorological parameters and tropospheric trace gases from aircraft. An airborne Lidar facility is under development using resources of the Applications and Engineering Directorates. Measurements to be conducted include temperature, pressure, $CO_2$ concentration, winds by Doppler shift methods, aerosol scattering, and the abundances of OH and $O_3$. The trace gas measurements are particularly important since reactions with OH determine the tropospheric residence times of a variety of natural and anthropogenic substances. The abundance and variability of OH in the lower atmosphere, however, is unknown. Measurement of ozone with aircraft-borne lidar will permit construction of a three-dimensional map to allow study of transport between the stratosphere and troposphere in the region of tropopause folds.

Theoretical studies have focused on the chemistry of both the free troposphere and the polluted air. Comparison of model calculations of carbon monoxide with available data concerning its latitudinal variation clearly shows the effects of industrial sources in the mid-latitude Northern Hemisphere. It also indicates a substantial tropical source which is as yet unidentified. Other model studies focus on the physical mechanisms of rainout processes and simplified treatments of radiative transfer for use in photochemical models.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Richard S. Stolarski
Telephone: (301) 344-5485

## PLANETARY ATMOSPHERES

The thrust of the GSFC effort in this area is to investigate the atmospheric and ionospheric properties of Earth and the planets, and to understand the influence of variable solar processes that effect both the short-term perturbation and the long-term evolution of these environments. Owing to the unique characteristics of each planet, including extreme differences in magnetic field and rotation rates, the study of comparative planetary responses to similar solar variations constitutes the best opportunity for advancing our understanding of solar-terrestrial relationships. Such relationships involving various forms of energy coupling are believed fundamental to achieving a full understanding of the energy balance of the near-Earth environment.

### Solar Variability and Atmospheric Response

The temperature distribution and the dynamic conditions operating in the atmospheres of the Earth and all other planets depend strongly on the characteristics of the solar radiation reaching the planet. GSFC scientists have shown that the variations both of the ultraviolet and the total solar radiation reaching the Earth as mea-

sured by instruments on a variety of space platforms (Atmosphere Explorer, Nimbus 7, and Solar Maximum Mission) can be understood in terms of the passage of regions of solar activity on the face of the Sun. These models are able to reproduce both the modulation (at the level ≤ 0.4%) of the total irradiance (or solar constant) observed in the past three years, as well as the ultraviolet radiation increase of up to a factor of three detected as the Sun went from minimum activity (about 1976) to maximum activity (in 1980). Variations of the solar radium known to have occurred between 1925 and the present are an additional source of variation of the total solar irradiance, although the effect of solar radius variations in the ultraviolet is negligible. The variations of the solar radiation due to structural changes (i.e. changes of the solar size) may be responsible for climatic changes known to occur in tens of years cycles, which in their most extreme cases are known as mini-ice ages.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Dr. S. Sofia
Telephone: (301) 344-6051

**Trillion-Watt Laser Discovered on Mars**

Goddard scientists have discovered that a natural laser is at work in the atmosphere of Mars, radiating infrared energy into space at a rate of one million megawatts. This is the first definite identification of a natural laser.

Despite the abundance of man-made lasers, based on solids, liquids and gases, scientists had not previously identified the phenomenon in nature. Emissions of bright light have been observed, for example, in the auroral glow from the Earth and its neighboring planets, but no one has proved that a population inversion exists and, therefore, that a laser is responsible. However, natural microwave amplifiers, known as "masers," occur in interstellar gas clouds; they operate like lasers but at far lower energies.

The Goddard team, led by Dr. Michael Mumma, discovered their laser by analyzing infrared radiation of about 10 microns wavelength, which is emitted by the carbon dioxide in the Martian atmosphere between 70 and 90 km above the planet's surface. That corresponds to the loss of vibrational (stretching) energy by the molecules. Other researchers, including Dr. Charles Townes, co-inventor of the laser, had noticed the strength of those emissions, but they could not be sure what was causing them.

Dr. Mumma's group succeeded by using an instrument developed at Goddard, known as an infrared heterodyne spectrometer. By analyzing the shape and intensity of the infrared bands, the scientists established that there was a hundred-fold population inversion; a hundred times more carbon dioxide molecules were in the upper than in the lower energy state.

The vibrational energy that powers the Martian laser comes originally from sunlight and is distributed among the carbon dioxide molecules by molecular collisions in the atmosphere. A population inversion is established because the atmosphere is so optically dense at certain wavelengths that the absorbed energy cannot escape: if a photon leaves one molecule it is almost immediately reabsorbed by another.

The 10-micron radiation from Mars is one thousand million times more intense than it would be if there were no laser effect and the atmosphere were in equilibrium. The total power of the laser across the daytime face of the planet is about one million megawatts; that is a thousand times the output of a large electric power station.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Michael J. Mumma
Telephone: (301) 344-6994

**Jupiter Exploration**

A Quadrupole Mass Spectrometer is being prepared by GSFC scientists for flight on the Jovian atmospheric entry probe as part of the Galileo 1985 mission. The primary objective of this instrument is to determine abundances and isotopic ratios of major constituents of the atmosphere of Jupiter as a function of altitude from the 0.1 bar to 10 bar pressure level. To aid in the search for minor atmospheric constituents with mixing levels less than $10^{-8}$ (the maximum range of the mass spectrometer) two independent chemical enrichment systems are employed. In addition, a noble gas purification cell is incorporated into one of the systems. This cell minimizes interferences with chemically active species and possible hybrid formation or background mass peaks. Samples of the high pressure Jovian atmosphere are introduced into the mass spectrometer sensor by four independently operated capillary leak arrays which reduce the incoming pressure system to values suitable for efficient mass spectrometer operation. The observations of the vertical variation of the composition will yield important information on the cloud composition and the dynamical properties of the atmosphere. Measurements will be made for a duration of 60 minutes after the 400 g deceleration during probe entry into the atmosphere in 1988.

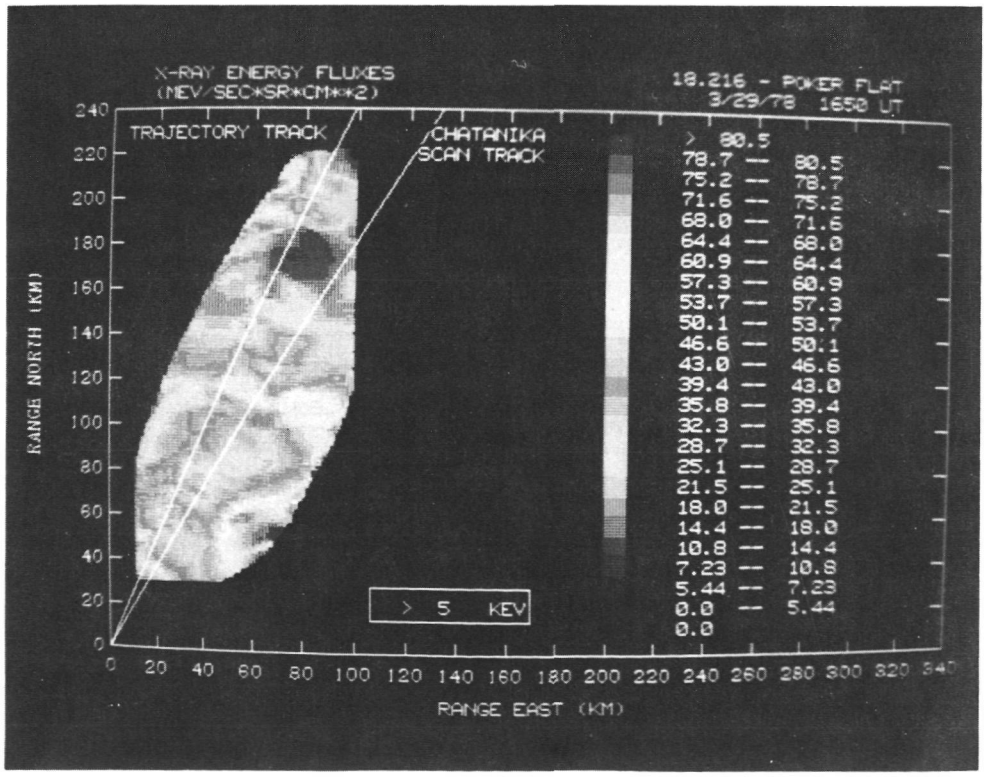
Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Dr. H. Niemann
Telephone: (301) 344-8706

### Atmospheric Perturbations

Investigation of perturbations of the Earth's upper atmosphere and ionosphere are being actively pursued, with both satellite and rocket experiments. In situ measurements of the variability of high latitude neutral winds are now being made on the Dynamics Explorer Satellite, launched in August 1981. These high-resolution electron temperature and density measurements are beginning to call attention to important new dimensions of upper atmosphere dynamics.

Remote sensing of auroral X-rays have permitted GSFC scientists to map and study auroral energetics induced by magnetospheric disturbances on both local and global bases. Recent rocket overflights from Poker Flat Research Range, Alaska, have provided scanned data sets of daytime and nighttime auroral X-ray structure, which have been converted to time-averaged images through digital colorgraphic techniques. A detailed study of the spectral characteristics of the emitting regions shows that the electron precipitation responsible for the X-rays is composed of a two-component energy distribution, where the less energetic component produces the emission enhancements in the bright regions. Comparison of the day-to-night events showed that the daytime event was spectrally harder and more structured in space than the nighttime event. This study demonstrated that when remote X-ray sensors are placed aboard orbiting spacecraft, they will provide a powerful tool for proving the global nature of magnetospheric particle radiations and their effect on the atmosphere.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Dr. R. Goldberg
Telephone: (301) 344-8603




*Example of a simulated color map of aurora x-ray energy fluxes emitted near 100 km This was obtained with a scanning detecto onboard an overhead rocket. The whit line marked "trajectory track" shows th path of the rocket flight.*



### Studies of Titan and Saturn

Electron and ion measurements made by the Voyager 1 Plasma Science instrument were used by GSFC scientists to study the interaction of Titan with Saturn's rotating magnetosphere. Using models for the pickup of exospheric ions outside Titan's magnetic tail and ion flow with the tail GSFC scientists found that the interaction between Saturn's rotating magnetosphere and Titan resembles the interaction between the solar wind and Venus or a comet. The interaction was characterized by the presence of a plasma wake surrounding Titan which was more dense and cooler than the surrounding magnetospheric plasma. These properties were related to the deflection of magnetospheric plasma around Titan and the addition of exospheric ions picked up by the rotating magnetosphere. Within the wake but outside the magnetic tail of Titan a significant reduction in plasma flow speed was found, providing evidence for mass loading by the addition of exospheric $N_2^+$ to the flowing plasma. A clear comet-like feature was found within the tail, where a flux of heavy ions was observed to flow away from Titan; the flux was interpreted to be $H_2CN^+$ escaping from the ionosphere.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Dr. R. E. Hartle
Telephone: (301) 344-8234

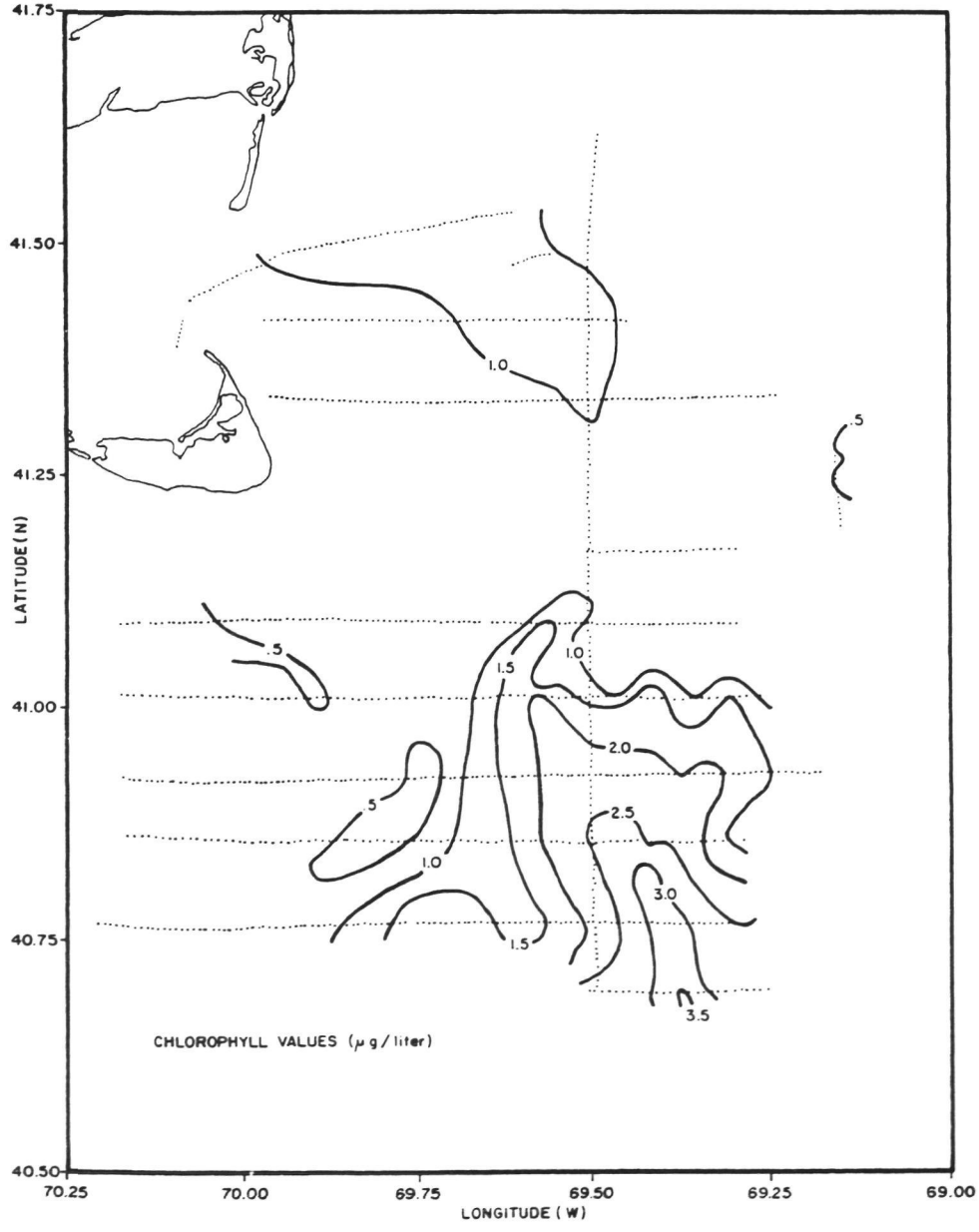
## SENSOR DEVELOPMENT

Innovative instrumentation and the expanded use of existing equipment has been required of NASA since its inception. An example of new instrumentation is the radar altimeter developed for the Topography Explorer (TOPEX) Program. This altimeter has been designed to surpass the specifications of the earlier one on Seasat; the goal is twice the precision of the Seasat altimater. A major step was taken toward this goal in building the module called the Digitial Chirp Pulse Generator with a 600MHz chirp bandwidth. This together with a three second averaging time for the height measurement is designed to have a 2 cm precision for non-stromy seas. Other existing instruments have been redesigned successfully or have produced new information. The Ocean Color Scanner has been upgraded from an aircraft system and certified for a Space Shuttle flight. The Airborne Oceanographic Lidar (AOL) has been shown to be capable of quantitative measurements of fluorescent photosynthetic materials, for example, chlorophyll a, that occur in mesoscale ocean features such as the warm core rings that are associated with the Gulf Stream; traditional oceanographic instruments and platforms have not been usable for studying these phenomena because of their size and motion. The Very Long Baseline Interferometer (VLBI) Network has shown 3-4 cm precision for length measurements; over great circle distances of thousands of kilometers. In addition the non-uniformity of the Earth's rotation was measured with a precision of 0.06 millisec.

### Airborne Oceanographic Lidar

Research activities with the Airborne Oceanographic Lidar (AOL) were performed utilizing both of the basic system modes of operation, fluorosensing and bathymetry. The fluorosensing capability of the AOL was significantly upgraded through the additions of (1) a real-time 2-channel display, (2) a new multiwavelength excitation capability, and (3) a software controllable voltage supply to individually set optimal voltage levels for the 32 photomultiplier tubes located in the receiver assembly. An in-house trade-off study was performed to provide decision options in favor of an excimer pumped dye laser for multiwavelength excitation.

The real-time display and visible two–laser multiwavelength capability were made operational for flight test and evaluation during a cooperative project as part of the Langley Research Center Phytoplankton Dynamics Experiment over Nantucket Shoals aboard the NASA P-3A aircraft. During these missions the use of two lasers simultaneously on an alternating pulse basis was demonstrated for the first time. A Warm




*Shown is a contoured map of the chlorophyll a distribution over the Nantucket Shoals.*

Core Ring 550 km east of Cape Cod was overflown during an excursion from the Nantucket Shoals Experiment. Significant amounts of fluorescence response in the 580 nm spectral region were found in addition to chlorophyll in the ring boundaries. This is the first airborne lidar overflight of a Warm Core Ring ever conducted. Final data analysis is now in progress for these field experiments.

Continued development of the AOL bathymetry and terrain mapping capabilities was extended to include the mapping of shallow water submarine features (< 2 m) and beaches in joint NASA/U.S. Army Corps of Engineers (COE) flight experiments conducted near Wrightsville Beach, North Carolina. The analytical effort in processing this data included the development of software for detailed comparison of laser scanning data with surface truth data or with laser data taken on other passes. Preliminary results indicate that the AOL has potential application for resolving a number of COE shoreline mapping problems, such as monitoring beach reconstruction.

Successful field experiments using this lidar include the airborne measurement of crude oil film thickness, ocean-dispersed tracer dye concentration and the simultaneous spectroscopic detection of the laser-induced Raman return and fluorescence from chlorophyll and other naturally occurring pigments.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Dr. Frank E. Hoge
Telephone: (804) 824-5567

**Altimetry**

The radar altimeter for the Topographic Explorer (TOPEX) Program is under development at Wallops Flight Center. This is another evolutionary step in the design of spaceborne radar altimeters that has already produced the GEOS-3 and Seasat instruments. Functionally similar to the Seasat-1 design the TOPEX altimeter will be significantly improved over the earlier system; the TOPEX instrument will have twice the precision of the Seasat device. In addition, the new altimeter will have precision ranging at two radar frequencies (Ku and C bands) (13.7 GHz and 5.45 GHz) which will allow the correction of errors due to ionospheric propagation. This system is designed to measure altitude to a precision of 2 cm for relatively calm seas (a significant wave height less than ten meters) and 3 cm when the significant wave height is between ten and twenty meters. The altimeter will also measure the significant wave height, a variable that roughly is the wave height that would be reported from shipboard; the accuracy is designed to be 0.5 m or 10% of the true value. The altimeter has a modular design which has been completed. The modules are now being worked on in detail. This past year two of them have been completed and are being tested; these two are the upconverter and the digital chirp pulse generator.

Much attention has been given to the analysis of altimeter data. Averaging the altitude measurements over many passes gives the shape of the Earth; subtracting this average from a single pass reveals the dynamic structure in the Earth's ocean surface principally the ocean currents such as the Gulf Stream. Analysis of the return pulse shape gives information about the wave height and other statistical properties of the waves such as skewness. This latter parameter is related to the new parameter "significant slope" which continues to hold promise for major additions to our knowledge of the oceans. The significant slope is a measure of the slope of the waves; as such it contains information about the probability of the wave breaking. This shows promise for understanding such diverse problems as wave attenuation and the air-sea interchange of gases.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Mr. J. T. McGoogan
Telephone: (804) 824-3411

**Chesapeake Bay Fronts Experiment**

Data was successfully collected for the Chesapeake Bay Fronts Experiment during the Fall of 1980 by several Wallops remote sensing instruments that were flown on the Wallops P-3A aircraft. Image processing support was also provided for the experiment. This pilot experiment, managed by LaRC, focused on the interpretation of aircraft SAR imagery of fronts so that the hundreds of Seasat SAR passes collected over the ocean could be better interpreted. Seasat SAR imagery of the Western North Atlantic area appeared to provide valuable information on the location of coastal fronts, as well as detecting surface layer structures whose origin is not presently understood. Wallops instruments included the Airborne Oceanographic Lidar (AOL) and the Surface Contour Radar (SCR). In addition, surface sampling was accomplished from boats during the experiment. Image processing support included the archiving of SLAR imagery and the overlaying of instrument data with a map for intersensor comparisons.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Dr. Frank E. Hoge
Dr. Ed J. Walsh
Telephone: (804) 824-3411/824-5698

### Atmospheric Chemistry

Wallops Flight Center carried out two tasks to aid in the understanding of the distributions, sources, and sinks of trace atmospheric species. The first accomplishment was the identification of means of improving the quality of high altitude ozone data obtained using balloon-borne Electrochemical Concentration Cell (ECC) ozonesondes. Apparatus was developed to quickly and efficiently determine sampling-pump performance under reduced pressures. Using this apparatus to individually test each pump eliminates an error of about 5% caused by using an averaged correction curve for all pumps.

The other accomplishment involved the successful participation in NASA's Global Tropospheric Experiment Test Flight, using aircraft instrumentation developed at Wallops for measuring nitric oxide. The flights demonstrated the system's capability to measure nitric oxide levels in clean areas of the troposphere where concentrations are extremely small. The data obtained also provides valuable information for developing and testing models of atmospheric chemistry.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Dr. Arnold L. Torres
Telephone: (804) 824-5553

### Climate Multispectral Cloud Radiometer

The Multispectral Cloud Radiometer (MCR) has flown on several NASA aircraft. Most recently, the MCR was flown on the WB-57 aircraft which took part in the Cooperative Convective Precipitation Experiment (CCOPE) Mission in FY80. The instrument is a scanning radiometer that passively measures cloud top reflected and emitted radiance. The instrument has a 7 milliradian instantaneous field-of-view that scans $\pm 45^{o}$ from nadir with a mirror rotational speed of 3.47 Hz.

The MCR has seven channels that span the near IR through the thermal IR region. Channel No. 1 is in the 0.75 micrometer region which provides a clear absorption channel used to determine cloud optical thickness. Channel No. 2 and Channel No. 3 are in the 0.76 micrometer region ($O_2$ A-Band) used in determining cloud top height. Channel No. 4 is in the water vapor absorption band (1.14 micrometer) and is currently being studied for its usefulness in cloud modeling. Channel No. 5 and 6 are in the 1.6 and 2.1 micrometer region and are used to distinguish the thermodynamic phase of the cloud water droplets. Channel No. 7 is in the thermal IR region (11.4 micrometer) which is used to measure cloud top temperatures. This channel has a dynamic range of $190^{o}K$ to $315^{o}K$.

The instrument as flown on the CCOPE Mission consisted of the scanner, control panel, data system, and tape recorder. The analog data from the scanner was digitized (simultaneous samples on all seven channels) at a 4.6 kilobit rate which was then converted into two pulse code modulated bit streams (200 kbits/sec.) for recording on the in-flight tape recorder. The tape recorder has a two-hour record time. There was also an accompanying ground station that


*Ground station for the Climate Multispectral Cloud Radiometer.*

provided uncalibrated "quick-looks" of the data when the aircraft returned after each data flight. Also, prior to each flight the instrument viewed a calibrated external target which provided a day-to-day observation for recording instrument consistency.

The instrument has been improved from the earlier version with better preamplifiers, better calibrations and a new data recording system so that the data is now of a higher quality.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. Dean E. Smith
Telephone: (301) 344-8591

**Earth Sciences And Applications**
**Very Long Baseline Interferometry**

Microwave radiation from distant radio sources (quasars, galaxies, and a few stars) is now an important tool for studying the dynamics of the Earth and the stability of its crust. From a network of large radio telescopes, the Crustal Dynamics Project acquires Very Long Baseline Interferometry (VLBI) data consisting of precise differences in time of arrival of the radio signals at the various telescopes. From these data the baselines between widely separated telescopes, the position of the Earth's pole, and the Earth's rotation can be inferred with great precision. Over a period of several years these observations will measure the contemporary motions of the tectonic plates which are a major, if not the major, factor in large earthquakes.

As part of the short 1980 Measuring Earth Rotation and Intercomparison of Techniques (MERIT) campaign, VLBI observations were taken for two one-week periods using radio observatories in Massachusetts, Texas, California, Sweden, Germany, and England. One-day measurements of the Earth's pole and rotation had a typical precision better than 5 cm and 0.06 millisec, respectively. Day-to-day repeatability in the 14 baseline lengths was typically 3-4 cm, or a precision of approximately a part in one hundred million. Baseline lengths derived from VLBI and satellite laser ranging agreed at the subdecimeter level.

VLBI data are also being used to define the celestial coordinate system. Since extragalactic objects have no detectable transverse motion, they provide a suitability fixed celestial reference frame. The radio and steller coordinate systems will be unified using data from the Hipparchos astrometric satellite, the Large Space Telescope, and lunar occultations.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. Charles E. Cote
Telephone: (301) 344-8215

**Sensor Development Ocean Color Experiment**

The Ocean Color Experiment (OCE) package was delivered to Kennedy Space Center in September 1979, to fly on the second Space Shuttle flight as part of the first Shuttle Program science package (OSTA-1). The instrument was designed and built by the Instrument Systems Division, Experiment Engineering Branch for the Office of Space and Terrestrial Applications.

The OCE is a scanning, imaging radiometer with eight channels in the visual and near-infrared spectrum with center wavelengths from 486 nanometers to 787 nanometers with 3.5 milliradians field-of-view. The instrument is in two packages with a combined weight of 246.2 pounds and consuming 176 watts operating power. Data is recorded by the onboard Shuttle Payload Recorder at a rate of 307 kilobits per second.

The scientific objectives of the OCE include determination of ocean bio-productivity, and observation and analysis of ocean circulation patterns. The OCE will gather approximately 120 minutes of data during the Shuttle's daytime passes over the open ocean. Primary studies will concentrate on the Southeastern U.S. bight, the western Central and South American upwelling zones, a comparison of the Japanese Kuroshio Current and the Gulf Stream, as well as validation of remote-sensing techniques for the atmospheric effects on ocean radiometry.

Another primary objective is to demonstrate that an existing low-cost aircraft sensor can be upgraded, environmentally tested, and successfully flown on the Shuttle. If this approach is successful, the cost of some space experiments could be greatly reduced, putting them within the reach of low-budget researchers.

The Ocean Color Experiment (OCE) was also one of six Earth viewing experiments conducted during the second orbital flight test of the Space Shuttle. The experiment was designed to map ocean features using an eight-channel scanning radiometer. The objective of the experiment was to demonstrate the ability to locate plankton or chlorophyll concentrations and identify circulation features by mapping color patterns in the ocean. These patterns occur due to the absorbing and scattering properties of water which alter the reflected light spectrum.

Eight strategically placed spectral channels of the scanner produced valuable information on water color signatures. A variety of ocean and atmospheric conditions were observed. Atmospheric turbidity conditions ranged from a near Rayleigh sky at the Bahama site of the Yellow Sea where conditions of Mie = 0.3, as est

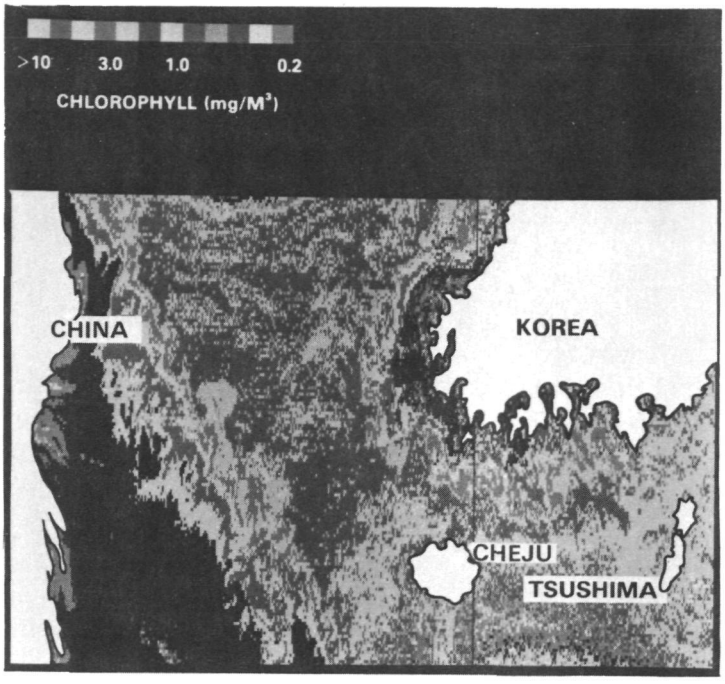
mated from OCE data, were encountered. The contribution of the atmospheric aerosols to radiometric signatures has been determined for some of the images.

Relatively low Sun angles in the Northern Hemisphere at the time of the mission and loss of opportunity to take data over areas off the East and West coasts of the U.S. due to cloud cover limited the amount of chlorophyll bearing water that could be observed. In addition, extensive cloud cover over frontal areas of the Kuroshio Current and the Gulf Stream during the STS-2 mission reduced the opportunity to observe mesoscale eddies. However, the 3-day mission produced chlorophyll images from the coastal waters of Portugal and the Yellow Sea.

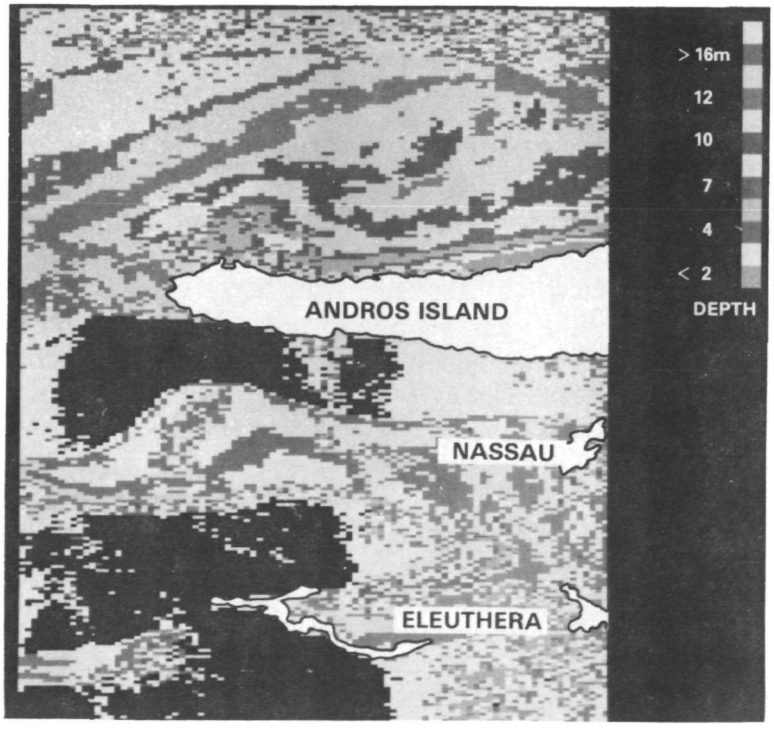
A patch of plankton extending several tens of kilometers was observed in OCE data taken during orbit 30 (November 14, 1981 at 10:40 a.m.) and orbit 32 (November 14, 1981 at 1:40 p.m.). Overlay of these successive images indicates a drift of the patch in the northward direction at a velocity of 1.5 km/hr. The process of inferring flow f elds from point measurements from successive space sensor coverages seems feasible if land features are used as stationary anchor points.

In the absence of chlorophyll, the blue-green spectral components of the light penetrates deeper into the water and reflects from the bottom to yield underwater topographic information. An ocean scene obtained during orbit 32 over the Great Bahama Bank in a spectral channel centered at 518 nm reveals very clear water conditions. The derived attenuation coefficient was about 0.02 $m^{-1}$.

The OCE has met its basic objectives by demonstrating the ability to map chlorophyll concentrations and identify ocean circulation features. In addition, underwater topographic features have been delineated in areas of clear water.




*Chlorophyll mapping over the Kuroshio Current.*




*Depth measurements obtained over the Great Bahama Bank showed very clear water conditions.*

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. Dean E. Smith
Mr. Hongsuk H. Kim
Telephone: (301) 344-8591/344-6465

**Subsurface Sounding**

Electromagnetic subsurface sounding is a remote sensing technique for investigating the Earth from the surface down to a depth of perhaps one kilometer. Uses for such a system include mineral exploration and water table location.

A prototype sounding system that mounts on a van has been constructed. In the use of this technique, a swept frequency electromagnetic wave is directed into the ground. Discontinuities in conductivity produce a secondary wave that can be detected back at a receiver. The multiple frequencies are used to give depth information; the lower frequency, the deeper the wave can penetrate.

Only recently has it been possible to predict theoretically the return to be expected from a realistic Earth. Several simple geometries have been studied, and the theoretical returns have been computed. The van-mounted system is being used to test the sensitivity of the system and the agreement with the theoretical predictions in preparation for an aircraft-mounted instrument.

Sponsor: Wallops Flight Center Director's Discretionary Fund
Contact: Wallops Flight Center
Dr. John D. Oberholtzer
Telephone: (804) 824-5241

**Surface Contour Radar**

Algorithms have been developed to take the aircraft effects out of the Surface Contour Radar (SCR) data. The corrected spectra from orthogonal flight lines have been combined graphically to produce higher resolution results than would be possible for a single flight direction. Algorithms for the digital combination of orthogonal flight lines have been developed and coding is nearing completion.

The SCR participation in the ARSLOE experiment, and comparisons of the directional wave spectra produced by the SCR with those of the various pitch and roll buoys are being made as the buoy data become available. Preliminary comparisons with data from the XERB and ENDECO buoys indicated agreement in both peak frequency and direction of the spectra. However, the SCR had superior resolution by about a factor of three.

Coincident data were obtained between the SCR and the Army side-looking aircraft radars (SLAR). The SLAR data are being analyzed by F.I. Gonzalez of NOAA PMEL so that a comparison may be made with the SCR spectra.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Dr. Walsh
Telephone: (804) 824-3411

**Radar Instrumentation For Entomology**

A combined analog and digital radar data acquisition subsystem was completed and field-tested in Georgia in September 1981. A biomation 8100 (100 MHz) waveform digitizer, a hardware logic box for signal preprocessing, a Hewlett Packard 9845T desktop computer, and a nine-track tape deck comprise the digital portion of the system. The logic box was designed and built by The Johns Hopkins Applied Physics Laboratory to form the interface between the high-speed waveform digitizer and the slower computer. Preprocessing of data in the logic box allows selection of the spatial region about the radar that is to be searched and the lower and upper video thresholds for digital data recording.

The analog portion of the subsystem allows range gate selection for peak detecting at multiple ranges and also allows for the display of a number of traditional radar functions such as the PPI and RHI. The subsystem was interfaced with a short pulse X-band marine radar that has been modified to include a parabolic antenna.

The overall radar system is being used by the U.S. Department of Agriculture for nighttime insect flight studies. During the September field program large numbers of individual insects and birds were detected at 0.2 to 2 kms range from the radar and recorded on digital tape. In addition, extended sources of insects were observed at times as stable masses over the nearby lighted city, sometimes as a massed dome above a highly lighted football field, on a few nights as well-oriented layers (up to five simultaneously) at altitudes up to three kilometers, and on one night as an extensive wide area mass movement of insects detected out beyond seven kilometers from the observing site.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Mr. J. T. McGoogan
Telephone: (804) 824-3411

**Meteorological Measurements Comparison**

Comparisons of radiosonde and rocketsonde data with data obtained from NOAA-6 are part of the larger satellite verification and calibration program involving Nimbus-7, Sage, SME, etc. During January-April 1981, comparisons at Wallops were made when NOAA-6 was within $1^{o}$ latitude of Wallops, and rocketsondes were generally launched within 30 minutes of overpass. Additional rocketsondes launched for other purposes were also used for comparisons, although the restriction of $1^{o}$ and 30 minutes were

more relaxed. Over 50 data pairs (rocket/NOAA-6) are presently being analyzed. Differences of the mean layer temperature (100 to 70 mbar; 70 to 50 mbar, ---, 1.0 to 0.4 mbar) range from less than $1^{o}$C up to $4^{o}$C at the highest altitudes. While these statistical means are showing good comparison, the individual profiles often don't agree.

A not-so-insignificant part of this effort is the multi-radiosonde measurements needed to identify the precision capability of this instrument. Preliminary results reveal that the temperature measurements obtained from the present radiosonde are repeatable to within $0.5^{o}$C or less, but the absolute measurement of pressure has many discrepancies which need further analysis. Precision of the rocketsonde instrument is better than $1^{o}$C up to 52-55 km. Results of this work are being published in October in the Journal of Geophysical Research (Green).

For the period November 1978 to the present, over 4200 satellite/rocketsonde pairs have been compiled for TIROS-N, and NOAA-6 at most of the North American rocket sites. Programs are being written to analyze the different seasons, different latitudes, and different events.

Sponsor: Office of Space and Terrestrial Applications
Contact: Wallops Flight Center
Mr. J. T. McGoogan
Telephone: (804) 824-3411

## EARTH SCIENCES AND APPLICATIONS

This program involves basic and applied research which focuses on improving our understanding of the physical and dynamical processes occurring within the Earth and on or near the Earth's surface, and on improving our ability to better manage the resources of the Earth. This research is conducted with emphasis on the use and evaluation of space-technology and remote sensing in particular. The research includes the development of models that make use of the inherent synoptic, high spatial density and repetitive attributes of remotely sensed data to represent the dynamics and interactions of processes occurring on or within the Earth. Independent analyses of remotely sensed data from various space missions provides quantitative evidence to corroborate these models or to identify where they need to be extended and improved in order to more accurately describe how the observed processes occur and evolve.

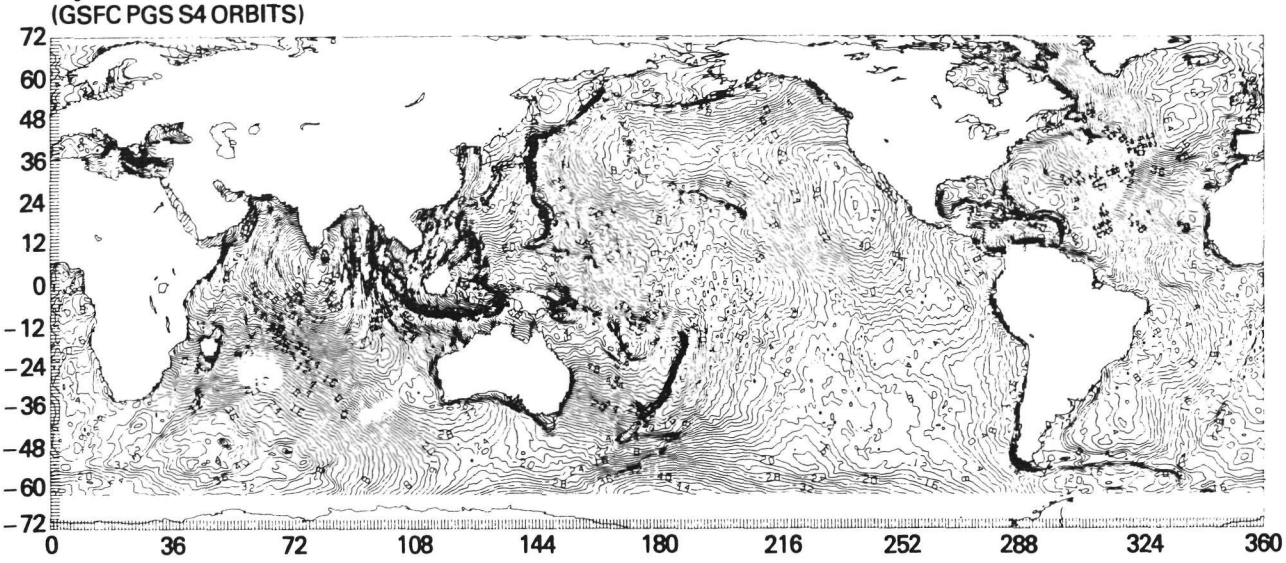
Supporting these efforts are fundamental research efforts to improve our ability to quantitatively interpret remotely sensed observations and improve remote sensing techniques applicable to Earth science studies. Research efforts in the past year covered a wide spectrum of disciplines including the geodynamics, geophysics, and hydrology and geology of the Earth, and associated sensor developments. Also studied were agriculture, forestry, water resources, land cover management and monitoring. An example of an area in which particularly noteworthy progress was made in the past year is the further development of models of the Earth's magnetic field as well as the completions of vector and scalar crustal anomaly maps that have utilized the improved, high quality data that came from Magsat 1.

### Geodynamics

Improvements in modeling the gravity field of the Earth have been made for the purpose of improving the accuracy of the geoid, particularly the long wavelength components, and for the reduction of ephemeris error for Seasat and Lageos. The geoid corresponding to the (4,4) portion of the gravity field now has an accuracy of better than 10 cm. The combination of laser, US-B and altimeter data have been used for the development of an improved gravity model for ephemeris computations on Seasat. Seasat ephemeris errors have been reduced from several meters to about 70 cm with this new model. A new model of the global oceanic geoid has recently been developed based upon a combination of the Seasat altimeter data and precision ephemeris from laser tracking observations. This new geoid, (mean sea surface) computed on a $1^{o} \times 1^{o}$ basis has an r.m.s. accuracy of about 1 meter.

Models of the Earth's gravity field are being studied for: the determination of density structure associated with major subduction zones; the elucidation of mechanisms by which apparent mass excesses at subduction zones are supported or compensated; and the estimation of the strength/rheology of the tongue of subduction lithosphere and the surrounding mantle. The gravity field is also being studied to provide estimates of the density structure inside the Earth, the stresses at the top of the mantle and to provide information on mantle convection processes.

Interest in improved knowledge of the Earth's gravity field for studies of processes taking place within the Earth has prompted the development of a gravity field mapping mission. The mission, consisting of two spacecraft in similar orbits at 160 km altitude and separated by a few hundred kilometers, senses the anomalies in the Earth's gravity field by the induced variations in the distance between the spacecraft. Precise measurements of the range-rate between the spacecraft enables the gravity field to be derived. It is planned that the two spacecraft will remain in orbit for




*Mean sea surface topography based upon Seasat Altimeter data.*

about 6 months and be "drag-free" -a system that compensates for the action of air drag on the satellite, thereby maintaining the spacecraft at its designed altitude of about 160 km. This mission, Gravsat, will map the Earth's gravity field to an accuracy of about 2.5 milligal (about 1 part in $10^6$) with a resolution of approximately 100 km, globally; representing an improvement of about two orders of magnitude over our present knowledge.

The primary reasons for requiring this improvement in our knowledge of the Earth's gravity field is to answer many important geophysical questions relating to the formation of continents and basins, for form and scale of convection in the mantle, and the processes that are taking place along the boundaries of the tectonic plates that cover the surface of the Earth. In addition, the gravity field provides the level surface, or geoid, that represents the mean level of the ocean in the absence of winds and currents and is an important reference surface in studies of ocean circulation.

The tracking of the Lageos spacecraft by a global network of laser ranging systems and the observation of extra-galactic radio sources using very long baselines interferometric VLBI techniques is providing regular measurements of the Earth's rotation and pole position. These measurements are being used to better understand the irregular variations in the length of the Earth's day and its relationship to changes in the wind structure of the atmosphere. Changes in the position of the pole of rotation are being studied to identify any relationship to earthquakes or other solid-earth phenomena. The analysis of laser ranging data to the Lageos spacecraft are also being used to improve our knowledge of the Earth's mass; and laser tracking, together with VLBI, are making regular measurements of the distances between points on several of the different tectonic plates that make up the Earth's surface, including North America, South America, the Pacific, Europe and Australia.

Commencing in October 1980, an experiment was performed to compare the ability of satellite laser ranging (SLR) and VLBI techniques to measure the baselines between several locations in the United States. The laser ranging sites were Greenbelt, Maryland; Westford, Massachusetts; Ft. Davis, Texas; Owens Valley and Goldstone, California. The VLBI scientists indicate precisions to better than 5 cm. The initial comparison of the four baselines shows agreement equal to or better than 8 cm on all lines.

Over a period of several years these measurements will determine the present-day motions of the tectonic plates which play a major role in the causes of and the occurrences of earthquakes.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. David E. Smith
Telephone: (301) 344-8555

**Geobotany, Geology And Geophysics**

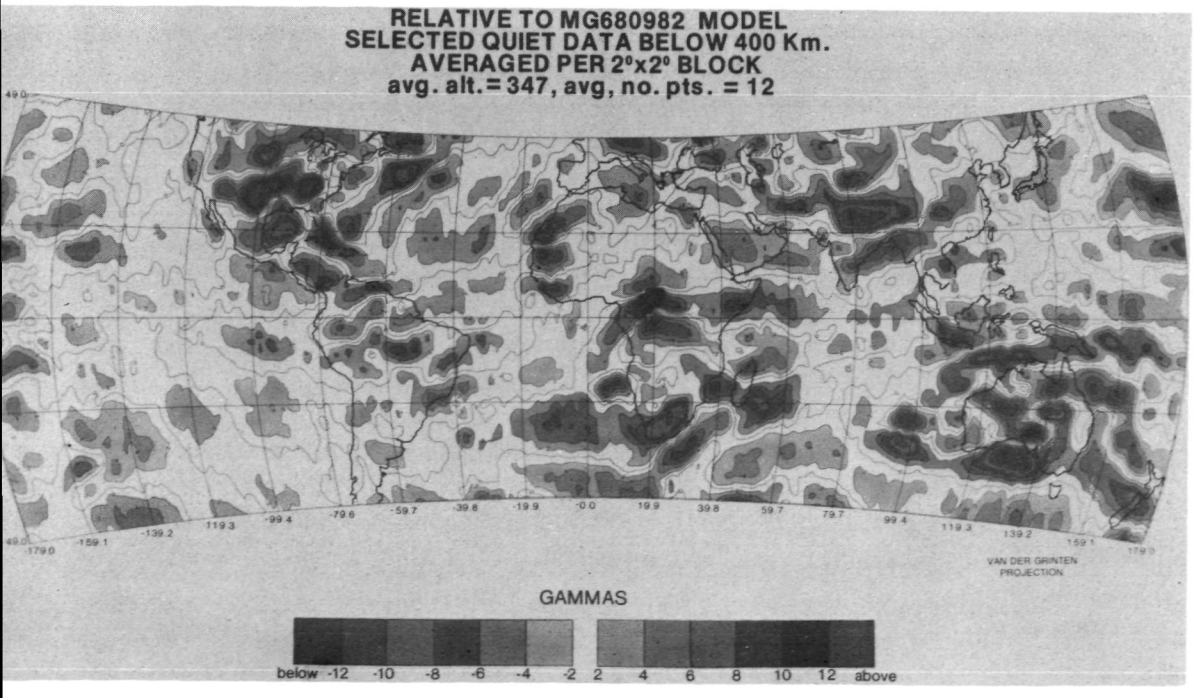
An extensive geobotanical field study continues to be conducted by GSFC personnel in the mineral sulfide district near Mineral, VA. Test sites have been laid out in two pairs of closely spaced mineralized and non-mineralized sites. The sites are thus arranged so that many of the environmental factors are similar, and the mineralized sites are arranged over former mine sites. Monthly vegetation and soil samples are being collected. Preliminary results indicate that reflectance bands .63-.69 μm and 1.55-1.75 μm corresponding to Thematic Mapper (TM) Bands 3 and 5 are higher in vegetation growing in mineralized soil versus non-mineralized soil but not in band .76-.90 μm (TM band 4). The best time to observe this phenomenon seems to be just prior to senescence. Further, the increase in reflectance is not a linear function of trace metal concentration, but rather, the concentration must be greater than some still unknown threshold value before the changes can be seen in the spectral response. The concentration of Cu and Pb are most consistently correlated with the observed spectral changes.

A great deal of information has been compiled for the Oslo, Baikal, East African and Rhine Graben rift zones as part of a systematic collection of satellite and surface data for continental rifts. Originally designed as part of an effort to compile a comparative Rift Atlas, emphasis is now turning toward the relationship of satellite geopotential data to major tectonic structures, using continental rifts as a major focus. Satellite magnetic anomalies in the southern Norway region near the Oslo Rift show good correspondence with depth-to-Moho contours and with the axis of Bouguer gravity highs. Less direct relations exist for the Lake Baikal rift region, although there is a correlation between the peak amplitudes in POGO anomaly patterns and topographic relief. Block models are being developed using the limited geologic data as constraints and the satellite data to determine the overall regional properties.

The International Association of Geomagnetism and Aeronomy (IAGA) selected definitive geomagnetic reference fields for 1965, 1970, and 1975 to which a GSFC model (GSFC 9/80) contributed. The GSFC (9/80) model combines observatory, marine, repeated observation at selected locations, and satellite data into a model for the 1960-1980 time period using significant new modeling techniques developed at GSFC. These include, for the first time, the solution for the magnetic anomaly fields present at the observatories. Such fields are a noise source for spherical harmonic models. Also incorporated for the first time were the third temporal derivatives of the secular variation.

Analysis of satellite magnetic anomaly data has progressed on several fronts. The region in and around Greenland is under investigation. A significant result is the inference of significant changes in crustal structure and/or petrology under the central part of Greenland. This was suspected from the nature of the coastal rocks and from gravity measurements but is now strongly confirmed, with delineation of some of the major crustal blocks, from the POGO magnetic anomaly data.

A modification of the equivalent




*Magsat Anomaly Map*

source program has been devised and tested which should result in more meaningful results, including the ability to derive equivalent relative magnetization at the geomagnetic equator. Developed in cooperation with mathematicians at the University of Maryland, the method consists of performing an eigenvalue analysis of the equivalent source solution, eliminating the eigenvectors which do not contribute significantly to the solution, and transforming back to the standard solution space. The resulting equivalent source dipoles continue to reproduce the measured anomalies very well but now these dipoles are forced into linear relationships in a way which eliminates spurious or "noisy" effects in the magnetization solution.

Studies are underway to determine the relationship of satellite magnetic data to large scale crustal properties. A crustal thickness map of the conterminous U.S. (sea level to top of the Mohorovicic [Moho] discontinuity) has been completed utilizing all available data from deep penetrating explosive refraction studies. These same studies contain data on the thickness of the intermediate crustal layer, i.e., the "basaltic layer" lying above the Moho and below the "granitic layer." The correlation between this intermediate layer, which is presumed to be the major source of the Earth's crustal magnetic field, and the POGO and Magsat magnetic results are now being investigated. It is planned to extend this study to include long wavelength gravity and structural information.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Charles C. Schnetzler
Telephone: (301) 344-5213

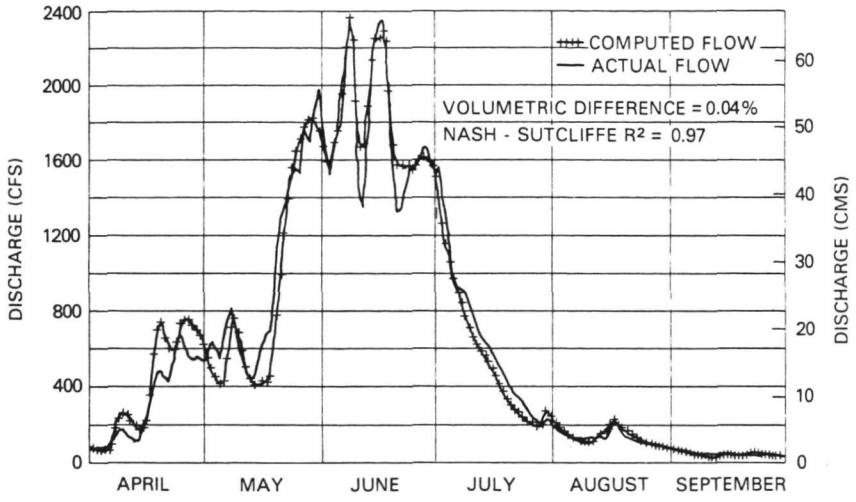
## Hydrology

A snowmelt runoff model using Landsat-derived snow-covered area data has been successfully employed for hydrograph simulation on river basins as large as 4000 $km^2$. Landsat images were used to extract the critical snow-covered area variable which was inputted to the model in combination with conventionally measured temperature and precipitation data. Simulated seasonal volumes for the years tested were within a few percent of the actual flow. Minor modifications are being made to the model to permit operational runoff forecasts in the Rio Grande Basin of Colorado. This model has potential for hydrological studies in ungauged watershed.

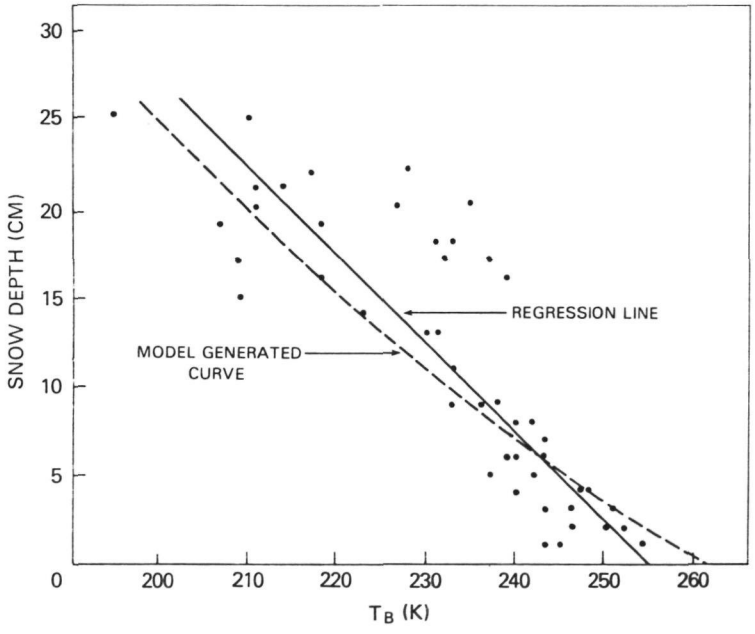
Other work in snow research has focused on developing and evaluating remote sensing techniques for determining hydrologically important snowpack properties, such as snow depth, water equivalent and wetness. These investigations currently emphasize passive microwave techniques because microwave radiation from snow-covered terrain comes from the ground and the interior of the snowpack, providing information about the amount, type and wetness of the snow. A recently developed radiative transfer model predicts microwave emissions from shallow to moderate-depth dry snow that agree closely with the microwave measurements obtained from truck-mounted and aircraft sensors. Although microwave radiometers in space have coarse spatial resolution (20 to 100 km), past research has demonstrated their ability to acquire useful information about snow depth in large uniform regions (such as Canadian High Plains, the U.S. Northern Great Plains and Central Russia). Work continues to extend these results to more heterogeneous areas like the forests of the Great Lakes, and to use a time series of satellite data to follow seasonal changes in the snowpack.

Visible/infrared data from the airborne scanner instrument, Thematic Mapper Simulator (TMS), was used to compare the effects of different spatial, spectral and radiometric resolutions on land cover classifications within a watershed. To determine the eventual utility of Landsat-D Thematic Mapper (TM) and Multispectral Scanner (MSS) instrument data, the aircraft measurements at 15 meter resolutions were averaged to simulate a 30 meter TM resolution and an 80 meter MSS resolution from space. Land cover classification accuracies were then compared under different conditions of spatial, spectral, and radiometric resolutions. In all cases (tested against combinations of 3, 4, 5 and 6 data channels), Thematic Mapper resolutions produced higher accuracies than the Landsat MSS. For specific land use categories, channels 8 (10.4 - 12.4 μm), 6 (1.55 - 1.75 μm) and 4 (.76 - 90μm) were important for delineation of residential areas, while channel 3 (.63 - .69 μm) was essential for good vegetation/forest identification.

In another effort, freshwater ice thickness of Walden Reservoir in north-central Colorado was studied using an aircraft-mounted Multifrequency Microwave Radiometer (MRMR) at four wavelengths ranging from 0.81 cm (37 GHz) to 6 cm (5 GHz). Assuming lake ice has few internal scatterers such as air bubbles, the amount of microwave radiation naturally emitted by the ice is proportional to its thickness. Therefore, thick ice will produce greater emissivity and brightness temperatures. Research indicated that the longest MFMR wavelength (6 cm) gave the highest correlation with ice thickness ($R^2$ = .98) using ice thickness values for four different time periods. In contrast, the shorter wavelengths were scattered by snow overlying the ice and produced




*Snowmelt runoff model simulated versus measured hydrograph for the south fork of the Rio Grande River of 1979.*




*Model generated curve of the snow depth versus the actual depths taken with truck mounted or aircraft sensors.*


13 MAY 1979


27 JUNE 1979

only poor information about ice thickness. The successful use of microwave remote sensing techniques to determine freshwater ice thickness has potential application to winter transportation considerations in commercially important areas like the Great Lakes.

Recent investigations have studied the utility of a variety of remote sensors to detect near-surface soil moisture content. Preliminary analysis of multispectral airfcraft data from the 1978 Guymon, OK and the 1980 Dalhart, TX soil moisture experiments indicates that combinations of passive microwave and visible/infrared data will provide the most complete assessment of soil moisture in agricultural fields, while combinations of active microwave and visible/infrared data produce improved classification of agricultural crops. Seasat Synthetic Aperture Radar (SAR) research has led to conclusions that vegetation in agricultural fields and grasslands, with the exception of corn, is effectively penetrated by L-band wavelengths (23.5 cm). The geometry of a corn canopy (either standing or after combining) produces high returns on microwave imagery which masks any moisture information from the soil beneath. Flooding under forest cover increases the radar return approximately 4.5 db above non-flooded forest areas. The mapping of flood extent under forest canopies can therefore be accomplished even under cloudy conditions with microwave sensors. Aircraft radar data collected before and during the Seasat study indicates that shorter vegetation when flooded produces similar increased returns at shorter wavelengths.

*Imagery taken with the SAR to show soil moisture near the surface.*

Although the Seasat SAR responds to differences in soil moisture with the same sensitivity as found with an airborne 19-cm wavelength scatterometer, the total range of response from dry to wet soil is less than the response to surface roughness. Therefore, monitoring soil moisture on a field-by-field basis will be very difficult with this active microwave sensor without prior knowledge of surface roughness conditions.

In related work, a parameterization of effective soil temperature was devised which eliminates the dependence of observed microwave emission on soil temperature. With this technique, it is possible to infer soil moisture conditions at a given test site through changes in microwave brightness temperatures without confronting the ambiguity arising from soil temperature variations. Studies of the spatial variation of soil moisture data indicates that surface soil hydraulic properties are highly variable with little or no spatial correlation beyond separations on the order of 10 m. A major objective for future work is the development of methods for averaging point measurements of these hydraulic properties through remote sensing to the appropriate spatial scales which are used in hydrologic, crop yield and general circulation models. Work is also continuing on energy and moisture balance modeling of the soil surface for estimation of actual evapotranspiration and soil moisture status. A relatively sophisticated computer model has been written to study these interactions as an aid to using thermal infrared and passive microwave remote sensing data in agricultural and hydrological research.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Albert Rango
Telephone: (301) 344-5480

**Earth Observation Sensors (Visible/IR)**

A major emphasis at GSFC in technology development for multispectral remote sensing is in the application of solid-state linear detector arrays to "pushbroom" sensor systems. Such sensors are capable of providing high spatial and spectral resolution and radiometric sensitivity.

Instruments using this technology are generally referred to as Multispectral Linear Array (MLA) sensors. In the past year, successful aircraft flights of a three-band MLA sensor were conducted and a more versatile four-band MLA sensor is near completion.

In addition, study efforts have been underway to develop concepts and preliminary designs for a sensor system which operates in spectral bands between 0.45 micrometer and 2.4 micrometers for an experimental land observing system. Such a system may ultimately evolve into the successor to the Thematic Mapper instrument which is scheduled for flight on the next Landsat mission (Landsat-D to be launched in 1982).

In support of the development of future MLA sensors, a broad program is underway to develop technology that is critical to such systems. These include development of visible, near infrared and shortwave infrared detector arrays, passive radiative coolers, wide field optics and spectral selection devices such as beam splitters and spectral filters. Laboratory systems have also been placed into operation to study and evaluate the radiometric and imaging performance of the advanced detector arrays.

In a related area, MLA technology is being pursued for application to the thermal infrared spectral region. In the past year, a program was initiated to develop photovoltaic, linear detector arrays for this spectral region. Such devices will be suitable for fu ture spacecraft sensors and shoulc open many new possibilities for high resolution thermal remote sensing for terrestrial remote sensing appli cations.

Sponsor: Office of Space and Terres trial Applications
Contact: Goddard Space Flight Center
Mr. Harvey Ostrow
Telephone: (301) 344-8107

**Forestry And Land Resources**

Spacecraft data studies continued to draw heavily on Landsat, with some inclusion of Seasat and NOAA 6 and 7 data. Landsat imagery is being used to detect forest disturbances such as defoliation by gypsy moths. Change detection techniques were developed to enhance measurement capabilities in areas of modest defoliation. Considerable effort has gone into integration of digital topographic data to explicitly account for topographically induced variation in radiance which otherwise masks valuable information. An Applications Pilot Test to transfer this remote sensing knowledge to the forestry community is nearing completion.

Urban land use and urban change have been investigated using Landsat imagery, Seasat SAR and several sets of aircraft data. Subsets of Thematic Mapper bands most suited for urban classification have been identified, and their advantages and disadvantages compared to Landsat Multispectral Scanner data have been documented. Classification is optimized when one band shortwave of .8 microns is combined with the .8 micron band and any other band in the shortwave IR.

The utility of Seasat SAR data in conjunction with Landsat MSS data for urban classification has also been investigated. The SAR instrument is useful in dry environments such a

Denver, but less useful in wetter complex environments such as Harrisburg, PA. The capabilities of the Thematic Mapper have been investigated in several environments in addition to the urban studies. When current classification schemes are used, high spatial resolution systems, such as the Thematic Mapper, provide more accurate mapping of certain cover types, such as wetlands, than low spatial resolution systems such as the Multispectral Scanner. However, the advantage in classification accuracy is less clear-cut for other scenes dominated by cover types such as mixed forest and farmland. For pure forest areas, the high resolution systems are equal to low resolution systems on an Anderson Level II classification, but clearly better on a Anderson Level III system.

There has been an active program to develop more powerful analysis tools in the form of contextual classification schemes. These schemes make full use of high spatial resolution data, such as that to be obtained by the Landsat-D Thematic Mapper.

The Advanced Very High Resolution Radiometer (AVHRR) on NOAA 6 and 7 is being used as a tool to study desertification in the Sinai Desert region and to measure global biomass changes. The difficulty of working with a very wide angle system is being turned to an advantage by studying the variation in atmospheric radiances as a function of time and location and doing "bootstrap" corrections.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Robert Murphy
Telephone: (301) 344-7282

**Agriculture**

Modeling studies aimed at improving the interpretability of remotely sensed crop temperatures have concentrated on developing inversion techniques for multiple view angle data. Experimental data for stressed row crops have been used with these models to infer separate crop and soil temperatures. A related effort of analytical modeling has produced a simplified form of the equation of radiative transfer which is used to relate radiances to crop production factors. The accuracy is comparable to that obtained with less rigorous empirical models, and the approach portends greater accuracies over a broader range of crop types and observation conditions. This two-stream model has been extended for use in spectral regions where multiple scattering predominates.

Using a principal component analysis of Kansas wheat data, Landsat radiance data were transformed into the physically meaningful variables of soil and canopy brightness. The qualitative relationship between the principal components and Leaf Area Index is similar to that found in the radiative modeling efforts discussed above.

Two major field experiments were conducted during the year. One was a joint USDA/GSFC experiment on row crop stress at USDA facilities in Phoenix, Arizona. Significant temperature variations were measured and the data successfully inverted to determine canopy and soil temperatures. Analysis of the evapotranspiration budget is underway. The second field experiment was conducted at the USDA Beltsville Agricultural Research Center (BARC) in Beltsville, Maryland. Spectral reflectance, thermal emission and a variety of biophysical measurements were made on stressed and unstressed soybeans. Data analysis is still underway. Laser-induced fluorescence was used as a method for measuring water stress for the first time. Preliminary analyses suggest this will be a useful adjunct to the field measurements program. In addition, controlled experiments involving $SO_2$ stress on tomatoes were conducted at BARC. Reflectances in the TM bands show significant changes as stress increased.

Considerable effort is still required to develop new measurement techniques or adapt and refine existing methods to do radiometry and spectroscopy in non-laboratory environments. Activities in these important supporting areas which have been conducted in the past year include work in low-cost field radiometers, instrumentation for bidirectional (multidirectional) radiance measurements and calibration systems. During the past year, modifications were made to improve the baffling of the widely used hand-held radiometers which were developed at GSFC, and a new spherically scanning radiometer was completed. A washable calibration target which can replace the conventional, non-washable, barium sulfate target, was developed and tested, and the effect of non-Lambertian reflectance on calibration was measured.

A successful overflight of the region surrounding GSFC and BARC was made using the Linear Array Pushbroom Radiometer (LAPR). The data, which were obtained as part of a system test, were supported by ground truth measurements to enable a study of bidirectional reflectance properties and establishment of the LAPR's radiometric accuracy. These studies will be completed during the coming year.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Robert Murphy
Telephone: (301) 344-7282

## INFORMATION EXTRACTION

Information extraction refers to the manipulation, processing, and analysis of data in order to correct it into useful information. It encompasses the design, development and operation of computer-based hardware and software systems required for the extraction of information products from digital data and requires the adaptation, development and use of related disciplines, e.g. data management. The following programs exemplify the development work GSFC is undertaking in this area of engineering research.

### Domestic Information Display System

The Domestic Information Display System (DIDS) was originally developed in 1978 at the request of the Executive Office of the President to demonstrate the potential of image display technology developed by the space program for the management and and display of geobased statistical information. During 1980, a prototype operational system was completed, including a central data management system and intelligent remote terminals.

DIDS is capable of merging statistical data with an on-line geographical data-base and interactively manipulating statistical class limits, color, and spatial resolution of the resulting choropleth maps. Single and bivariate histogram plots may be processed, and time-lapse displays dynamically show shifts in geographical distributions of population, income, and other demographic variables. Through distributed management of data catalogs and communication of selected variables, the remote terminal serves as a window on the larger data base of the central host system.

In October 1980, the host and one remote terminal system were transferred to the DIDS Program Office of Administration, Executive Office of the President. Renamed the Decision Information Display System, it is now providing operational support of policy analysis and planning in Federal Government agencies. A second remote terminal was installed in February 1981 at the University of South Carolina in Columbia to make this technology available for state applications. Coordination of this NASA-sponsored pilot system with other states is performed by the Council of State Governments. DIDS software and documentation is available from NASA's Computer Software Management and Information Center (COSMIC).

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. John T. Dalton
Telephone: (301) 344-6276

### Pilot Atmospheres Data System

The Pilot Atmospheres Data System (PADS) program is a multi-year effort directed toward the development and demonstration of effective data system capabilities, including the interconnection of applications data systems, to provide space application researchers and others with improved access to readily useable data and data products. Major technological concepts currently being evaluated relate to computer network interfaces, data system interconnection, and interactive catalog and data set access/exchange in a distributed system environment. Application of developed data system capabilities is directed in support of selected OSTA weather, climate, and upper atmospheres research programs.

During 1981, the PADS program has completed the first phase in the development of a System of Networked Applications (SNAP), a distributed network supporting packet communications and both catalog and data set access among heterogeneous processing systems. At present, the SNAP includes the interconnection of three separate data analysis/management systems at GSFC and a configuration of eight processors at the University of Wisconsin, all involved in severe storms, local weather or climate-related research. These processors consist of 16-, 24-, and 32-bit minicomputer architectures from two different computer vendors. Designs have also been developed for implementing the network data handling service software of the SNAP on an IBM-compatible mainframe in 1982.

The user-oriented network services presently provided within the SNAP enable an interactive terminal user on any computer system in the SNAP to make queries for and access data sets from any other computer system in the network. A uniform user interface to all network services has been provided to all GSFC hosts even though different data inventories and set management systems are used on each host. The network interfaces and the multilayered communication and application level protocols of the SNAP have been designed in cognizance of the evolving standards for system interconnection.

Extension of the SNAP to incorporate at least four additional GSFC processors and to include additional user-oriented distributed data access service functions has been planned for 1982.

Sponsor: Office of Space and Terrestrial Application
Contact: Goddard Space Flight Center
Mr. J. Patrick Gary
Telephone: (301) 344-6079

**Pilot Climate Data Base Management System**

The Pilot Climate Data Base Management System (PCDBMS) will serve as a focal point for managing NASA's large collection of climate-related satellite data. The PCDBMS will provide uniform data catalogs, inventories, and access methods for selected NASA data sets. It will also provide appropriate data manipulation facilities so that research users can easily combine or compare data sets, and so that they can acquire data that is compatible with other computer facilities where the data will be used. This pilot system will focus current data management activities, demonstrate the capabilities of an automated data base management system, provide limited but useful support for climate research, and carry out related data management research and development directed toward the evolution of a comprehensive, fully automated data management system. In FY81, a preliminary hard-copy catalog was developed, and work was started on the automated catalog and inventory. In FY82, the PCDBMS will install a dedicated computer and begin limited operations to demonstrate the system to selected climate researchers.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. Lawrence V. Novak
Telephone: (301) 344-9538

**Data System Technology Program**

As part of the NASA Data System Technology Program, GSFC is conducting various applied R&D activities in data base management systems (DBMS). The purpose of these activities is to assess, develop, and demonstrate techniques for applying DBMS technology to NASA's satellite data management problems and to transfer this technology to current and future missions. Fiscal Year 1981 activities included:

- Comparative analysis, evaluation, and performance testing of DBMS systems to determine their applicability for managing extremely large volume satellite data bases;
- Functional specification of a Packet Management System (PMS) utilizing a DBMS to catalog, store, retrieve packetized satellite data ingested at rates up to 50 million bits per second;
- Applied research in the development of a common user interface to distributed, heterogeneous databases, including specification of a preliminary methodology based on formal logic theory.

In Fiscal Year 1982, DBMS test and evaluation will continue, the PMS will be designed and implemented, and further research in user interfaces will be done.

Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Ms. Karen Posey
Telephone: (301) 344-9040

**Transportable Applications Executive**

Increasing software development costs and the difficulty of transferring programs between computer systems motivated an effort in 1980 to design a common executive to be used in software systems currently under development for remote sensing applications. This Transportable Applications Executive (TAE) will provide system services commonly required by data analysis software, including interactive user control through menus, commands and command procedures, input parameter processing, error handling, and image and file management. Machine and operating system dependencies will be isolated in interface sub-routines to facilitate conversion of the executive to other systems. Because of the common interface provided by the executive, analysis programs written to use its services will be installed and run on other computer systems operating under TAE.

Following completion of a conceptual design in November 1980, a prototype version of the system was completed in August 1981 which operates on Digital Equipment Corporation VAX 11/780 computers. The prototype TAE provides user interface and parameter processing functions. The design of a complete operational version of the system will be completed in 1982.

One of the first software packages to run under TAE will be a General Meteorological Package (GEMPAK) currently under development to analyze temperature, humidity, and other parameters which are derived from satellite observations. This system of analysis programs provides capabilities for the mathematical analysis of observations and the ability to produce gridded fields and the display of contour maps, vertical soundings and cross-sections. GEMPAK includes device-independent graphics subroutines that will be generalized for use in TAE to provide a common, transportable interface to a variety of color and monochrome display devices and plotters.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Mr. David R. Howell
Telephone: (301) 344-9041

## SPACE APPLICATIONS TRANSFER

Remote sensing applications development and transfer activities are carried out at GSFC primarily by the Eastern Regional Remote Sensing Applications Center (ERRSAC). The major elements of ERRSAC are the Regional Remote Sensing Applications Program (RRSAP) and the Applications Systems Verification and Transfer (ASVT) program. The Multispectral Linear Array (MLA) research program directed by ERRSAC aims at establishing and validating performance parameters of future satellite remote sensing systems. GSFC's objectives and recent accomplishments in these areas are summarized in the following paragraphs.

### ERRSAC

Through workshops, training, participation in state programs, contracts, technical assistance, and the 10-week American Society of Engineering Education (ASEE) summer faculty research program Eastern Regional Remote Sensing Applications Center (ERRSAC) interacted with universities and colleges in each state in its region. Its university activities were highlighted by the Conference on Remote Sensing Education (CORSE-II) at Purdue University on May 18-22, 1981, which attracted 200 participants from college faculty throughout the United States. CORSE-II concentrated on instructional materials in remote sensing, low cost digital processing systems, and the roles of NASA and NOAA in remote sensing education. Proceedings are now available.

In an effort both to assist universities in remote sensing education, and to provide a remote sensing training tool to practicing professionals, ERRSAC prepared a Landsat Tutorial Workbook, now in press.

ORSER and OCCULT (ORSER Complete Conversational User Language Translator) programs were available on a commercial time-sharing network (Uni-Coll Corporation) in FY81 and were used for ERRSAC projects and training activities.

The Algorithm Simulation, Test and Evaluation Package II (ASTEP-II) image analysis system developed last year was successfully tested and has been implemented on computers at the University of Maryland and the State University of New York at Albany. The image processing requirements of state and local agencies in Maryland and New York are now being served by these installations. In addition, a modified version of the ORSER processing system developed at the Pennsylvania State University has been installed at the Virginia Institute of Marine Science at the College of William and Mary. This system is now being used routinely to implement a variety of remote sensing programs throughout the State.

ERRSAC is continuing to develop computer programs to demonstrate digital image processing concepts. The Apple Image Processing Educator (AIPE) system has been designed and written to take advantage of the color-graphics capabilities of the Apple II minicomputer.

Among the state Landsat applications projects and special interest projects which ERRSAC has been involved in during the past year are the following:

ERRSAC participated in the establishment of the Maryland Remote Sensing Steering Committee. This group meets quarterly to define state remote sensing requirements and to direct implementation strategies. A statewide forest mapping project commitment has been made with the Maryland Department of State Planning and a similar project has also been proposed in Maine.

HCMM satellite data have been integrated with Landsat Multispectral Scanner (MSS) data to produce improved land use/land cover classifications for Clark County, Ohio.

Furthermore, ERRSAC completed a literature survey of the applications of satellite remote sensing to water quality monitoring issues, and a study has been initiated to assess requirements and potential applications of the architecture-engineering community for satellite remote sensing.

Special interest groups, such as the U.S. Army Corps of Engineers (USACE), the Nuclear Regulatory Commission (NRC), and the Pennsylvania Power and Light Company (PP&L) have also applied remote sensing technology in several projects with support for ERRSAC.

ERRSAC has worked with the USACE Districts in Rock Island, Illinois and St. Louis, Missouri on a demonstration of the application of Landsat data to floodplain management, particularly natural resource inventory and dredged material disposal. A larger cooperative program of remote sensing research, involving the Landsat-D Thematic Mapper as well as the current Landsat MSS, is planned. The program will examine many applications, including flood control, floodplain management, damage prediction, water quality and dredging navigation sites all over the country, from Washington State to Georgia.

A three-way project incorporating the expertise of ERRSAC, NRC and PP&L has been initiated during the year. The objective of this work is to demonstrate the applicability of satellite remote sensing data for incorporation into a geographic information system (GIS) developed for long range regional planning models.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Philip J. Cressy
Telephone: (301) 344-7658

## RRSAP

Regional Remote Sensing Applications Program (RRSAP) has concentrated on developing and transferring germane uses of Landsat data to the 19 states within the regional boundaries of ERRSAC. States outside this region are serviced by similar applications centers at Ames Research Center and the Earth Resources Laboratory.

The primary objective of the Regional Remote Sensing Applications Program has been the establishment in state and local governments of the institutional environment and technical capacity for interpreting satellite remote sensing data and integrating the results into routine resource management and analysis. To date, programs in a dozen states, involving nearly 50 projects and the training of nearly 150 state and university personnel, have resulted in successful adoption of Landsat technology in Minnesota, Vermont and New Jersey, with Maryland and Virginia about to follow suit.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Philip J. Cressy
Telephone: (301) 344-7658

## ASVT

An Applications Systems Verification and Transfer (ASVT) program to assess the application of enhanced Landsat imagery for hydrocarbon exploration in Appalachia was carried out jointly by ERRSAC, the Appalachian Regional Commission, and geologists from seven Appalachian states. The project demonstrated the utility of lineaments identified on Landsat imagery as an exploration tool in the search for petroleum in Appalachia.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Philip J. Cressy
Telephone: (301) 344-7658

## MLA

The Multispectral Linear Array (MLA) research program is a comprehensive effort to establish spatial, spectral, and radiometric performance requirements or alternatives for nadir and off-nadir observation by a satellite remote sensing system involving MLA detectors. In support of this program, ERRSAC has studied the effect of spatial resolution and band selection on image information content. The work to date uses texture analysis as a means of quantifying the ability of a particular sensor configuration to characterize the spatial frequency of ground targets.

Sponsor: Office of Space and Terrestrial Applications
Contact: Goddard Space Flight Center
Dr. Philip J. Cressy
Telephone: (301) 344-7658

Page intentionally left blank

Page intentionally left blank

# IV

# Flight Projects and Mission Definition Studies


*During Fiscal Year 1981, engineers at GSFC have been involved in planning and development of a number of new satellite programs and projects directed toward obtaining maximum use of space-derived data.*

## SHUTTLE ATTACHED PAYLOADS

The Shuttle era brings with it a new potential and challenge for NASA. Beginning in the 1980's, the Shuttle will provide routine two-way access to space and will eliminate many constraints imposed by present modes of space operations. With the Shuttle, manned and unmanned experiments can be conducted within a single mission. Large satellites can be deployed into orbit or can be retrieved for refurbishment and reflight. An entire class of experiments covering a wide variety of science and applications disciplines can be conducted while remaining attached to the Shuttle cargo bay.

During Fiscal Year 1981 several new payload systems have been developed. These include:

### Solar Optical Telescope Observatory

A Solar Optical Telescope (SOT) Observatory is now being planned to conduct detailed solar observations from space. It will yield more definitive data so that we can better understand the effects of the ever changing Sun's phenomena on our universe. The Space Shuttle enables returning the Observatory (the SOT Facility and the Science Instruments) to the ground for refinement between observations, to further enhance the study of the Sun.

The Science Instruments observe solar images provided by the collecting optics of the SOT Facility, or collecting optics internal to the instruments, for concurrent viewing of solar areas of interest over long periods of time. Because the solar images will be displayed on the ground in real time, the scientists conducting the observations will be in a position to quickly zero in on solar features that rapidly change in an unpredictable fashion. Observations presently made on the ground with great difficulty over many months will be made from space in a few hours with spatial resolutions approximately three times better. The SOT Observatory will also permit recording high resolution synoptic sequences over a period of several days from space, as opposed to minutes or seconds from ground based observations. In summary, the SOT Observatory incorporates all of the advantages of a ground based telescope in addition to yielding more accurate solar data than was ever possible.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. Thomas R. Buckler
Telephone: (301) 344-7792

### Shuttle Science Payload OSS-1

The first scientific applications and technology payload for NASA's new Space Transportation System (STS) was completed at GSFC, where it was designed, built, tested, and integrated by a team of engineers and scientists.

The assembled instruments are currently planned to fly on STS-3 scheduled for March 1982. The primary objective of the STS-3

mission is to evaluate performance of the Shuttle systems in planned modes of operation and to measure the environments associated with operation of the Space Transportation System. Its secondary objective is to provide early demonstration and verification of Space Shuttle's research capabilities for science, applications, and technology.

Experiments on OSS-1 have scientific objectives that are expected to be achieved on the early flight in the disciplines of space plasma physics, solar physics, astronomy, and life sciences all of which are represented by one or more instruments.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. D. Burrowbridge
Telephone: (301) 344-7692

**Office of Space Science OSS-3**

The GSFC has recently been selected as the mission management center for the OSS-3 payload. Mission definition studies are nearing completion and development contracts have been awarded for the scientific instruments. The payload is currently scheduled for launch in early 1985.

The OSS-3 mission will represent many firsts for NASA and GSFC; the first mission requiring the efforts of four NASA Centers (GSFC, JSC, KSC and MSFC) and NASA Headquarters; the first mixed cargo mission for GSFC, the first GSFC use of the standard Spacelab pallet and igloo combination; the first NASA use for the gimbaled pointing system being developed under MSFC management (AGS).

The scientific objective of the mission is to perform astronomical studies of the universe in the ultraviolet spectrum from a highly stabilized platform on the Shuttle. Three instruments have been selected to yield ultraviolet imagery, far ultraviolet spectrophotometry, and ultraviolet spectropolarimetry. Simultaneous observations of most astronomical sources is planned to maximize the scientific return.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. Earle Young
Telephone: (301) 344-5233

**Detached Shuttle Payloads (DSP)**

Experience with prior sounding rocket flights has been applied to the opportunities presented by the Space Shuttle. This has resulted in development of a concept called Experiments of Opportunity Payloads (DSP) which provides for the flight of scientific instruments on the Space Shuttle by using free-flying payloads.

The DSP is independent of Orbiter's power, data, and pointing systems. Integration and qualification of such free-flyer payloads would be like that of present-day rocket payloads, and would result in a ready-to-fly system being delivered to Kennedy Space Center for installation into the orbiter, once a launch opportunity arose.

A flight test of this concept is planned, centered around an X-ray experiment which has flown aboard four separate S/R missions. Work has started on the DSP Test mission leading to a projected launch aboard the Shuttle in 1983.

Once in orbit, the Shuttle will use its Remote Manipulator System (RMS) to release the DSP payload. The DSP package will then operate in the preprogrammed manner totally independent of the Shuttle orbiter to obtain data from a number of X-ray sources. Data will be collected and stored aboard the DSP using a sounding rocket data handling system along with a low-cost aircraft tape recorder, while power is to be provided by sounding rocket-type batteries. The attitude control system is based upon the STRAP system now in use aboard sounding rockets, and uses a combination of low-drift gyroscopes and stellar and solar sensors to stabilize and point the DSP for data collection. Cold gas "bang-bang" pneumatics taken from sounding rockets will be used to provide control torques.

Thermal control will be provided by a simple thermal system of insulating blankets and heat rejecting doors.

After 24-40 hours of operation, the DSP payload will be retrieved by the Shuttle and stowed in the payload bay for return to Earth.

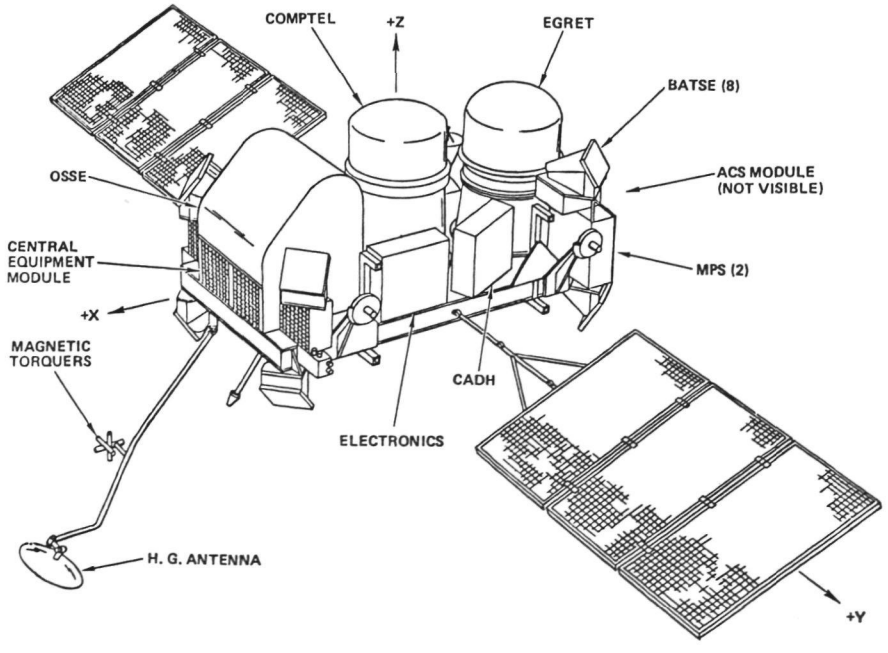
Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. Leonard Arnowitz
Telephone: (301) 344-8813

*Schematic diagram of the Gamma-Ray Observatory and the placement of the instruments selected for the mission.*

## GAMMA RAY OBSERVATORY (GRO) MISSION

The objective of the Gamma-Ray Observatory (GRO) mission is to study the most energetic photons originating in our galaxy and beyond. These photons provide the most direct means of studying the largest transfers of energy occurring in astrophysical processes. In particular, the GRO will address the following critical topics in astrophysics:

- Study of the dynamic evolutionary forces in compact objects such as neutron stars and black holes.
- A search for evidence of nucleosynthesis--the fundamental building process of nature--particularly in the environment of supernova.
- Study of gamma-ray emitting objects whose nature is not yet understood.
- Exploration of our galaxy in the gamma-ray range, especially with regard to regions difficult to observe at other wavelengths; the origin and dynamic pressure effects of the cosmic rays; and structural features, particularly related to high-energy particles.
- Study of the nature of other galaxies in the energetic realm of gamma-rays, especially radio galaxies, Seyfert galaxies, and BL Lacertae objects and quasars.
- Study of cosmological effects through the detailed examination of the diffuse radiation and the search for primordial black hole emission.
- Study of intense gamma-ray bursts of many types whose origins remain a mystery.




Four scientific instruments have been selected for the Gamma-Ray mission: A High Energy Gamma-Ray Telescope (EGRET), A Compton Telescope (COMPTEL), An Oriented Scintillation Spectrometer Experiment (OSSE), and a Burst and Transient Source Experiment (BATSE).

Sponsor: Office of Space and Terrestrial Applications (OSTA)
Contact: Goddard Space Flight Center
Mr. J. J. Madden
Telephone: (301) 344-8963

## GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (GOES)

During Fiscal Year 1981, the GSFC supported NOAA in developing plans for an advanced version of the current series (D, E, F) and the proposed series (G, H, I) of operational environmental satellites in geosynchronous orbit. The advanced system is expected to utilize new instruments that are rapidly approaching state-of-the-art status with particular emphasis on more vertical soundings and improved resolution. The advanced system also addresses improvement in architecture of ground data handling and dissemination to users. The space segment will be designed to make optimal use of Shuttle launch capability including spacecraft sizing for tariff consideration.

Sponsor: Office of Applications
Contact: Goddard Space Flight Center
Mr. Richard Worth
Telephone: (301) 344-8992

## SEARCH AND RESCUE SATELLITE-AIDED TRACKING (SARSAT) PROJECT

SARSAT will provide a demonstration of aerospace technology to the Search and Rescue (SAR) community by detection and location of downed aircraft and ships in distress. The Search and Rescue Mission of the Tiros Project at the GSFC is responsible for the U.S. portion of the SARSAT Project, an international cooperative project involving the U.S., Canada, and France. NASA is the system manager of the U.S. participation which includes NOAA, DOT, and DOD. Canada provides the spaceborne repeater for relay of the 121.5 and 234 MHz signals from Emergency Locator Transmitters (ELT's) carried by approximately 200,000 U.S. aircraft and Emergency Position Indicating Radio Beacons (EPIRB's) carried by some ships. France provides a spaceborne processor for experimental ELT's and EPIRB's operating at 406 MHz. The U.S. integrates these two instruments onboard three of the NOAA environmental satellites. Each country provides its own Local User Terminals (LUT's) and test beacons as well as strong participation by the SAR users in the demonstration of the system. The location of the ELT's and EPIRB's is accomplished with the same doppler location principle demonstrated by satellite data collection systems such as the Nimbus RAMS and the ARGOS system. The Soviet Union is also cooperating with the SARSAT partners by making its own SAR satellite system, COSPAS, interoperable with the SARSAT system.

Sponsor: Office of Applications
Contact: Goddard Space Flight Center
Mr. G. W. Longanecker
Telephone: (301) 344-6868

## EXPERIMENTAL LAND OBSERVING INSTRUMENT DESIGN

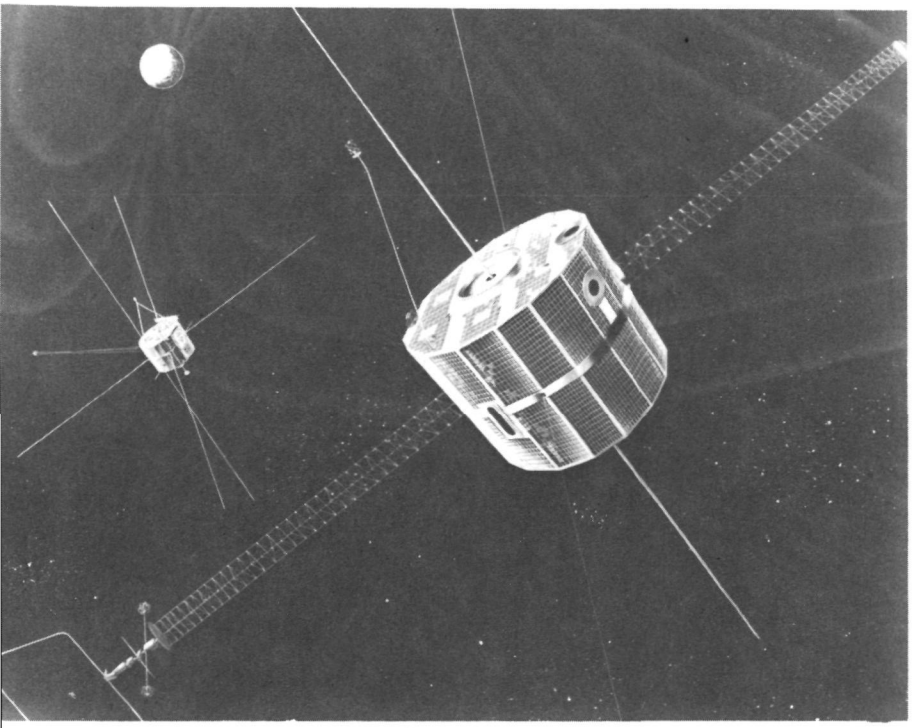
During Fiscal Year 1980 the GSFC initiated multiple studies for the definition of an Earth resources remote sensing instrument that would utilize solid state focal plane detector arrays operating in the "push-broom" scan mode. This instrument would offer multispectral imagery at high resolution, on-board data processing, cross-track viewing, and stereo imaging capability. The design definition of this instrument, known as the Multispectral Linear Array (MLA), has resulted in five different design approaches with unique solutions to the MLA instrument design requirements. Results to date substantiate the feasibility of instrument designs to provide high resolution, radiometrically calibrated imagery over a $15^{o}$ field-of-view with four bands (10 m resolution) in the visible and near IR, and two bands (20 m resolution) in the short wave IR. Data rates are compatible with the tracking and data relay satellite system and for direct data transmission utilizing data compression. These studies are due for completion in FY 1981 and will provide design schedule and cost information that will be used in preparation of MLA performance specifications for hardware development, and for definition of instrument system parameters for an Experimental Land Observing System mission in the late 1980's.

Sponsor: Office of Applications
Contact: Goddard Space Flight Center
Mr. Edwin Speaker
Telephone: (301) 344-6311

## DYNAMICS EXPLORER SATELLITES

The dual satellites, called Dynamics Explorer (DE) 1 and 2, were stacked together on a Delta 3913 launch vehicle and placed into coplanar, polar orbits from the Western Test Range, Lompoc, California on August 3, 1981. The objective of the Dynamics Explorer program is to investigate the strong interactive processes coupling the hot, tenuous, convecting plasmas of the magnetosphere and the cooler, dense plasmas and gases co-rotating in the Earth's ionosphere, upper atmosphere, and plasmasphere.

The dual DE satellites work together to acquire data simultaneously in the magnetosphere by one spacecraft and in the ionosphere and atmosphere with the second. Since the Earth's magnetic field especially channels energy and particles between these regions, operations are especially planned to acquire data at two altitudes along the same magnetic field line region. Since the coupling processes take place predominantly in the higher latitude regions where the magnetic field lines are nearly vertical, the polar orbits also provide the passage of the spacecraft through the most interesting regions of near-Earth space. One spacecraft, DE-1, moves in a high orbit, 23,170 kilometers above the Earth. It carries video cameras to photograph the changing patterns of the northern lights, which are excellent signatures of the transfer of massive amounts of energy from the magnetosphere to the upper atmosphere. Detectors of ionized particles and of magnetic and electric fields, as well as a variety of receivers of electromagnetic (radio-like) waves which are naturally and man-generated, are used to characterize the environment.



*The Dynamics Explorer Satellites shown in co-planer, polar orbits simultaneously acquiring data in the magnetosphere and ionosphere.*

Meanwhile, DE-2 is skimming above the atmosphere from pole to pole. Because of its lower orbit, it moves much faster and makes many more observations of the polar regions. More importantly, it passes through the upper atmosphere and ionosphere, where the external disturbances are most intense and easier to measure. Instruments measure million-ampere electric current sheets running along magnetic field lines into, through and out of the ionosphere. Since the ionosphere is a resistance, it is heated by the currents, with heating rates as high as those from sunlight. Instruments also measure the resultant winds, which blow as fast as 1,000 miles/hour. Long antennas measure electric fields, which produce electric potentials of tens of thousands of volts across the polar cap, and which are apparently transmitted along magnetic field lines from interplanetary space.

Especially interesting to the scientists is the origin of intense electron beams which shoot down from space into the atmosphere and light it up with the glow and flashing of the northern lights. To study what gives these electrons their speed, the coplanar orbits have been carefully chosen to intercept the same stream at different altitudes at about the same time. There exist many clues--from observations of the streams by single spacecraft to measurements of intense radio noise bursts--suggesting that "nature's electron gun" is located between 3,000 and 8,000 miles above the polar regions. But it will be the role of the DE spacecrafts working together to supply the hard and detailed evidence as to what exactly is taking place.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. George D. Hogan
Telephone: (301) 344-5977

## GRAVSAT/MAGSAT-A

The GSFC is currently in the planning stages for a Gravitational Satellite (Gravsat) combined with a Magnetic Satellite (Magsat) Mission. This mission is to consist of two low altitude (160 km) spacecraft in essentially the same polar orbit with a following distance of 100-300 km. The objective of the mission is to model the fine-scale ($1^{o}$ x $1^{o}$) variations in the Earth's gravitational and magnetic fields. The fundamental measurement to be used in this analysis will be the range rate between the two satellites recorded at 4-sec time intervals. With a 6-month mission lifetime, over 3.6 x 106 measurements would be obtained to estimate the approximately 40,000 $1^{o}$ x $1^{o}$ mean gravity and magnetic anomalies covering the surface of the Earth.

The spacecrafts each contained a DISCOS system. This is a 4-inch ball inside a cavity that senses the position of the ball. In flight, the balls are essentially affected by nothing but the Earth's gravity field, which they follow. The spacecrafts are forced to keep the cavities centered around the ball, in all $6^{o}$ of freedom. The force is provided by reaction wheels and gas jets, especially jets to compensate for air drag at this low altitude. About half the weight of each spacecraft is rocket fuel. A magnetometer on a rigid boom is installed on one of the spacecraft.

The Gravsat/Magsat Mission is to substantially improve knowledge of the fine structure of the Earth's gravitational and magnetic fields. The Earth's gravitational field contains information about the Earth's distribution of mass and can be used to construct a model of the geoid, which is the equipotential surface that would coincide with sea level if the oceans had no tides or currents and there were no interaction with the atmos-

phere. Satellite altimetry, in combination with the geoid, which can provide the instantaneous height of the ocean surface, can be used to study global ocean circulation, which is an important factor in meteorological and climatological research. Further, because the Earth's gravity field reflects the distribution of mass within the Earth, it can be used to explore the existence, form, and scale of convection in the Earth's mantle. Mantle convection is thought to play a major role in the driving of the plates; and how and why the tectonic plates move is a fundamental but unsolved question in geophysics with important implications for our understanding of the occurrence of earthquakes. In addition, gravity can also be used to study continental and oceanic lithospheric features (such as mountains and ocean trenches) caused by collision of plates, and to study the mechanical properties of the plates themselves.

The Earth's magnetic field is of vital interest in four areas. One is the general orientation of the magnetic field lines as utilized for navigational purposes. Secondly is the temporal variations in the magnetic field that are as much as 7 percent over a ten-year period. Third, the anomalies in the field distribution which are related to the geological structure of the anomalous region. Fourth, the temporal magnetic variations in localized regions that have occurred since the Magsat-A Mission that will provide information on the characteristics of the Earth's core.

The combined data will be obtained at a lower altitude than previous data of either type. Gravitational and magnetic data give implementing information about the nature of the Earth, about geological features such as composition, temperature of rock formation, geological structure (faulting, subsidence, etc.), and the tectonic plate driving forces.

The simultaneous measurement of the gravitational and magnetic fields produced by the Earth's structure will provide information never before available. On a global scale, this time-correlated information combined with the expected resolution will provide knowledge of the Earth's structure to allow identification of location and availability of non-renewable resources such as petroleum and mineral ore.

Sponsor: Office of Applications
Contact: Goddard Space Flight Center
Mr. Thomas Keating
Telephone: (301) 344-8613

## COSMIC BACKGROUND EXPLORER (COBE)

This astrophysical mission will perform cosmological observations which relate to origin, energy and evolution of the universe. In particular, Cobe will make a definitive exploration and study of the diffuse radiation of the universe between the wavelengths of one micrometer and 13 millimeters. This band includes the 3K cosmic background radiation thought to be the residual radiation from the hot Big Bang which started the present expansion of the universe. It also includes the infrared region from one micrometer to 300 micrometers where the diffuse radiation of the universe has yet to be detected. This infrared band may include a large portion, if not the dominant part, of the energy content of the universe, including the radiation from primeval galaxies. The prospective launch time is the late 1980's on the Space Shuttle.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. Roger A. Mattson
Telephone: (301) 344-7751

## MATERIALS PROCESSING SPACE CRAFT

During FY 1981, GSFC wa assigned by NASA Headquarters t develop the design concept for an un manned Materials Processing Space craft that can stay continuously i orbit for five or more years, but b unloaded and resupplied with new materials every six months by an STS Orbiter. The spacecraft that GSFC conceived can supply the material processing experiments and produc tion equipment that it carries with up to 5,000 watts of continuous electri power, more than any other space craft in use. It provides a stable, quie platform for delicate operations, with maximum acceleration forces less than 0.001 g for continuous periods of six months or more. The spacecraft use the Multimission Modular Spacecraf modules and other currently existing space technology almost completely but assembled in a new way. The spacecraft is designed in complete modular units, any of which can be exchanged in orbit by the astronauts using the Remote Maneuvering Sys tem arm, without Extravehicula Activity.

The target payload the spacecraf is designed to carry is the McDonnell Douglas "Electrophoresis Operations in Space" (EOS) automatic produc tion plant for separating and purifying medical materials. This plant wil weigh 10,000 pounds and will require 3,500 watts (3 million calories pe hour) of continuous heat rejection a $5^{o}C$. To accomplish this, in the pre sence of thermal radiation from the solar array at over $100^{o}C$ and from Earth at $20^{o}C$, GSFC has concep tually designed an innovative therma radiator panel using variable conduc tance heat pipes. These heat pipes are bolted directly to heat exchangers in the EOS production plant. The pump of the production plant circulate the

operating fluid through the heat exchangers for cooling. Breadboard type tests of this panel indicate it will work successfully.

The medical materials the EOS may produce in large, affordable quantities include these universally needed products:

- BETA cells, a single injection cure for diabetes.
- Erithropoietin, stimulates red blood cell production in anemia.
- Interferon, improves viral infection immunity.
- Epidermal Growth Factor, promotes healing of skin burns and wounds.

The spacecraft itself provides a minimum cost, Shuttle-serviceable platform for carrying other kinds of factory modules to make materials that require low accelerations or unlimited vacuum for their effective production.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. Frank J. Cepollina
Telephone: (301) 344-5913
Mr. David H. Suddeth
Telephone: (301) 344-7697

## MULTIMISSION MODULAR SPACECRAFT (MMS)

The first of two production Multimission Modular Spacecrafts was delivered to the Landsat-D Mission Integration Contractor in April 1981. This followed the first application of the GSFC protoflight MMS spacecraft, the first Shuttle-compatible free-flyer spacecraft, used with the Solar Maximum Mission launched in February 1980. These spacecrafts are designed for launch on the Delta expendable launch vehicle and are fully compatible with the Orbiter for launch, on-orbit service and retrieval by the Space Transportation System.

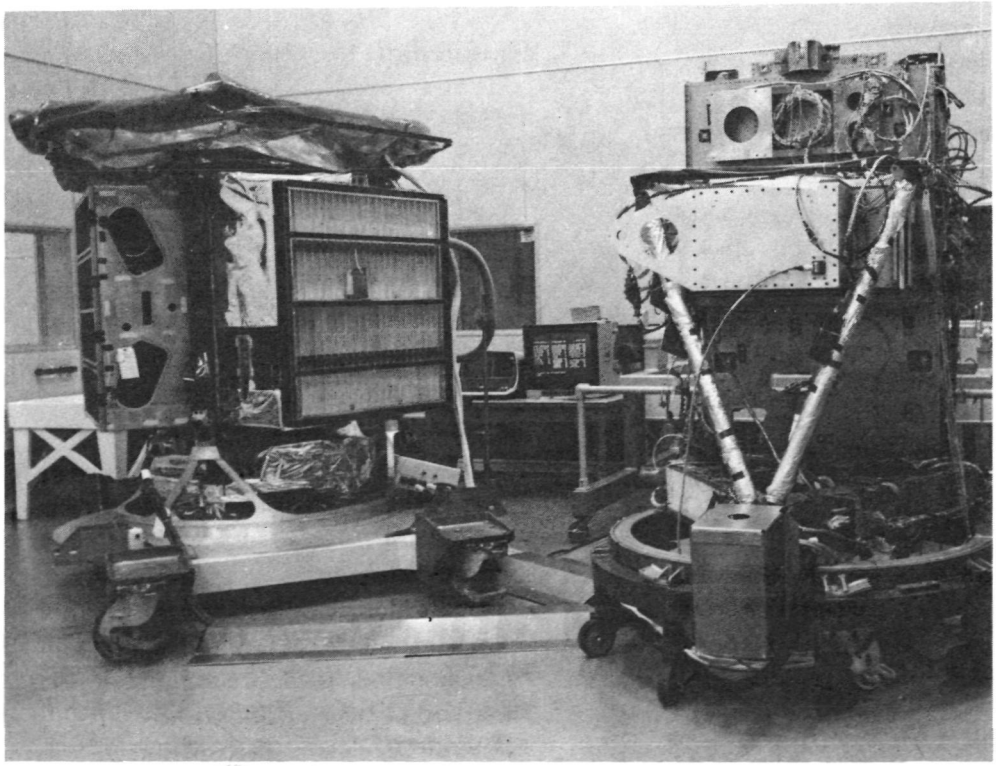
A flight support system was developed and delivered in FY81 which consists of three cradles that can be flown separately or in combination in the Orbiter to support a variety of MMS and other mission requirements. By utilizing a system of remotely-operated latches and a rotating berthing platform, the Flight Support System can support and manipulate free-flyer spacecraft for on-orbit deployment, service, repair or retrieval missions. The control avionics and rotating positioning platform are scheduled for completion next year.

Sponsor: Office of Space Sciences
Contact: Goddard Space Flight Center
Mr. Frank J. Cepollina
Telephone: (301) 344-5913

## LANDSAT AND ITS APPLICATIONS

Landsat is the first of a generation of unmanned satellites dedicated to repetitive surveillance of the continents and adjacent coastal waters to gather data for a variety of practical applications in Earth resources. For example, information is being acquired by Landsat on the distribution, growth states, and anticipated productivity of both natural and cultivated vegetation. This information is of value to diverse users such as agronomists, pedologists, recreational planners, conservationists, park rangers, and water engineers. Likewise, analysis of Landsat data are being performed to study landform classification, crustal deformation, dynamic Earth-moving processes, and areas for exploration of metals and oil. Other applications such as land use and

*The Multimission Modular Spacecraft being prepared and tested for flight at the end of next year.*



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

(cartographic) mapping are important to cartographers and land use planners.

Landsats 2 & 3 are now in operation. A second generation system, Landsat D and $D^1$, is now under development. Enhanced data quality with improved spatial spectral and radiometric resolution and a highly automated 48 hour turn-around data facility will be provided.

Sponsor: Office of Space and Terrestrial Applications (OSTA)
Contact: Goddard Space Flight Center
Mr. Jon Busse
Telephone: (301) 344-6142

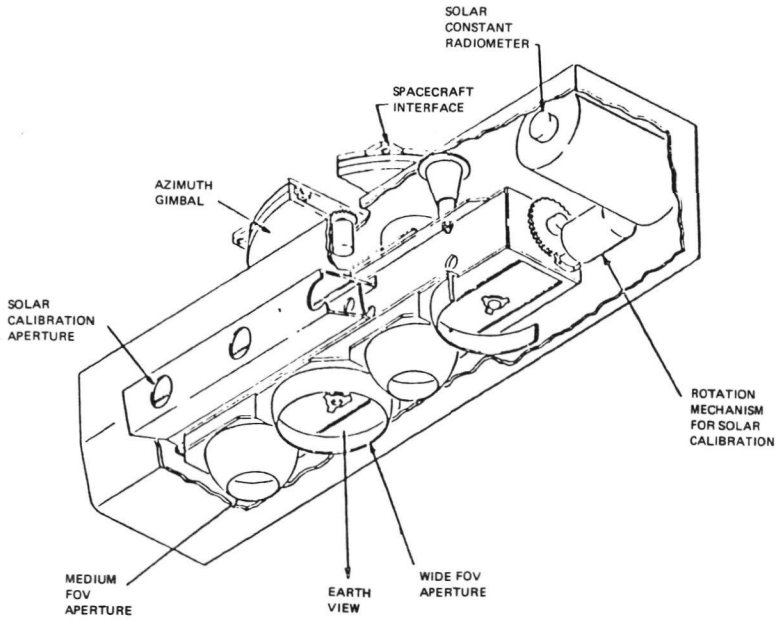
## EARTH RADIATION BUDGET MISSION

ERB is a three satellite system for obtaining measurements of the reflected solar flux and emitted flux from the Earth in order to map the radiation budget for the atmosphere. For example, studies of geographical and seasonal variations of the radiation's budget will be conducted.

The three satellite system is made up of two polar orbiting TIROS operational spacecraft (NOAA-F & G) and a mid-inclination ERBS. All three spacecraft will carry ERBE instrument sets. The procurement of the ERBS spacecraft was initiated early in 1981. ERBS will be one of the first spacecraft to be launched by Shuttle and released as a free flyer. It will also communicate through the new Tracking and Data Relay Satellite System. ERBS will transfer itself from the Shuttle orbit of 300 KM to its mission orbit of 600 KM. The ERBS will also carry the SAGE II instrument, a seven-channel photometer to map the distribution of stratospheric aerosols, $NO_2$, and Ozone on a global basis. This data will provide an understanding of the environmental quality of the stratosphere and its effect on climate.

The Goddard Space Flight Center is cooperating with the Langley Research Center in the execution of this program.

Sponsor: Office of Space and Terrestrial Applications (OSTA)
Contact: Goddard Space Flight Center
Mr. Carl L. Wagner, Jr.
Telephone: (301) 344-7230




*A schematic diagram of the components which make up the Earth Radiation Budget System.*

## ORIGIN OF PLASMAS IN THE EARTH'S NEIGHBORHOOD (OPEN)

This mission study will be the first comprehensive study of the flow of energy through the geospace system, including the near-Earth solar wind, the Earth's magnetosphere, the ionosphere, and the upper atmosphere. The collective behavior of these highly interactive component parts determines the overall behavior of the geospace system.

During Fiscal Year 1981, evaluation of responses to NASA's Announcement of Opportunities has proceeded toward selection of experiments for the mission. Instrument definition studies will be conducted by the selected experimenters in the next fiscal year to provide more detailed instrument information.

Measurements will be made to trace the flow of matter and energy through the system from input by the solar wind to ultimate deposition into the atmosphere; to understand the physical processes controlling the origins, entry, transport, storage, acceleration, and loss of plasma in the Earth's neighborhood; and to determine the role of these processes in our delicately balanced environment. The expected launch date is the late 1980's.

Sponsor: Office of Space Science
Contact: Goddard Space Flight Center
Mr. Kenneth O. Sizemore
Telephone: (301) 344-5108

# V Space Tracking and Data Systems


*Efficient and reliable tracking, data acquisition and communications are essential for all NASA flight operations if they are to meet their specific objectives. GSFC is pursuing several programs to develop new techniques necessary for the tracking, acquisition, and handling of data from future flight programs.*

## NETWORK SYSTEMS

GSFC activities in the network systems area include the development of improved tracking, spacecraft-to-ground communications and more efficient network operations and control technology.

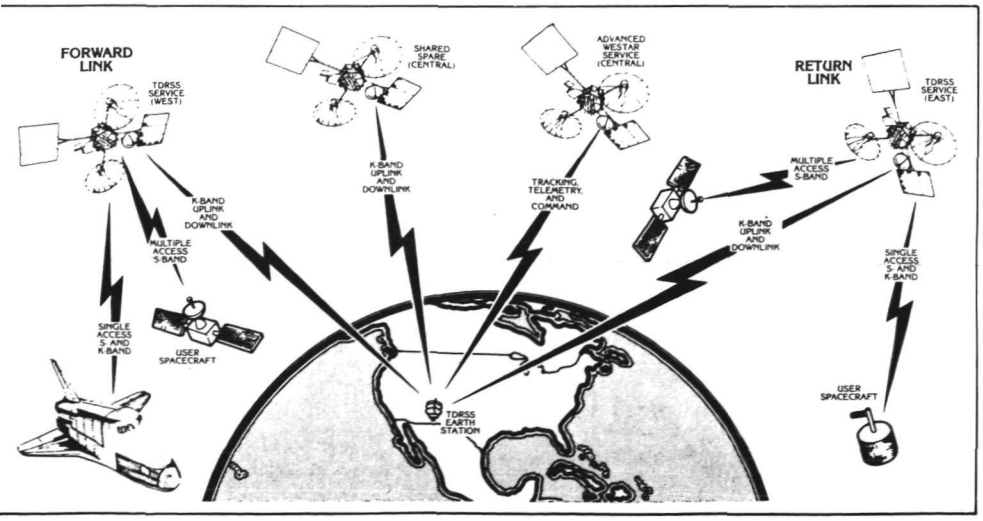
### TDRSS Communications Link Modeling

The Networks Directorate Communications Link Analysis and Simulation System (CLASS), which is an end-to-end communications link analysis tool for evaluating the TDRSS user link performance, has been expanded to include additional analysis capabilities. Models for the RFI environment, as well as the self-interference environment along with the analysis techniques required to determine the effects of these environments on the performance of the links have been developed and incorporated into the operational CLASS software. Modeling and analysis techniques for predicting system acquisition performance and tracking performance for all standard links have also been completed and incorporated into the CLASS system.

Efforts currently underway include providing a capability to evaluate link performance evaluations during launch and powered flight, predicting the degradation of the atmosphere on the user to TDRS and TDRS to ground links under a dynamic situation and the inclusion of user vehicle and antenna dynamics within the analysis system. Concurrent with these efforts, total system validation, utilizing data from ongoing TDRS System tests, is underway.

This model and the analysis techniques are capable of providing performance analysis of the user forward (command) and return (telemetry) links, as well as the internal TDRSS space-to-ground and ground-to-space links. The performance parameters that can be analyzed are bit error rate, bit slip rates, tracking system accuracy, acquisition times for all components, and loop lock statistics. The effects of the new models can be included in all of the various types of analysis which can be performed by the CLASS system.

*Tracking and Data Relay Satellite System*




Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Robert Godfrey
Telephone: (301) 344-5258

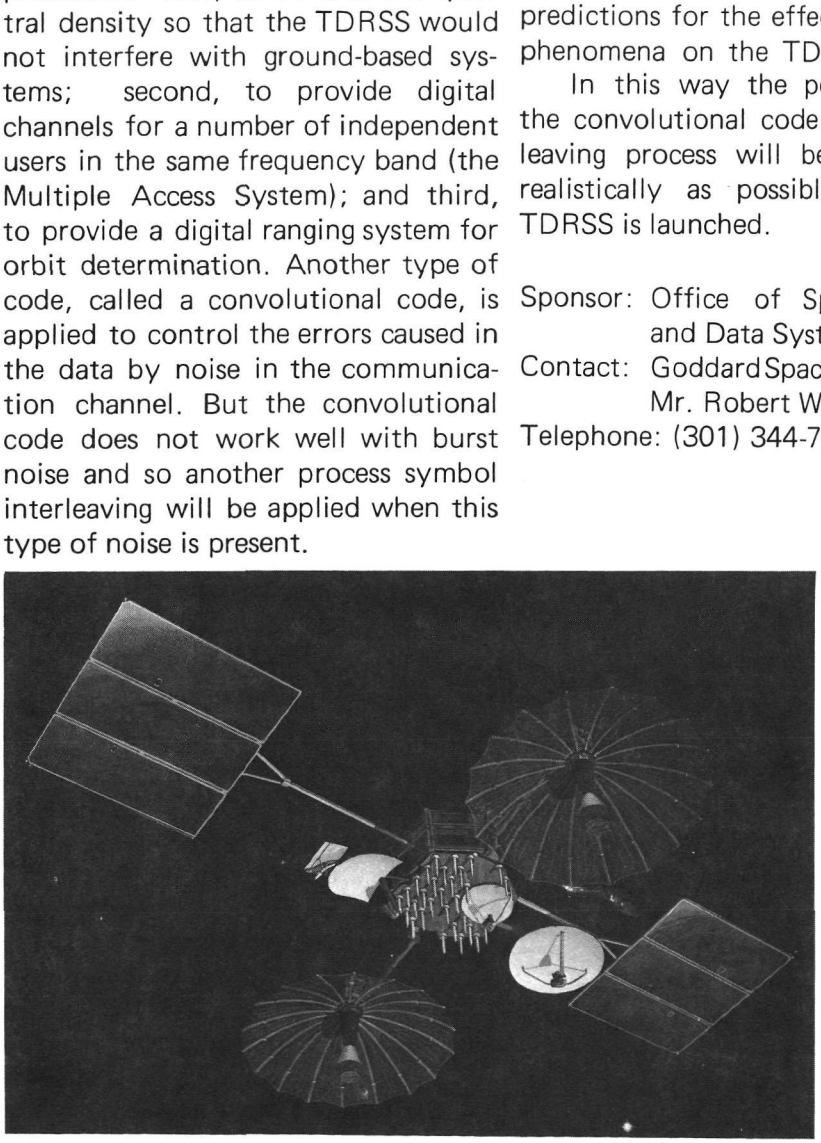
### Validating the Performance of the TDRSS Radio Frequency Communication Links in the Presence of Pulsed Radio Frequency Interference

The TDRSS RF communication links between the relay satellites and the user spacecraft are extremely complex digital signals consisting of two types of codes and, if necessary, an additional process is applied called symbol interleaving. The first kind of code, called pseudorandom noise code, was developed to solve three problems: first, to control the spectral density so that the TDRSS would not interfere with ground-based systems; second, to provide digital channels for a number of independent users in the same frequency band (the Multiple Access System); and third, to provide a digital ranging system for orbit determination. Another type of code, called a convolutional code, is applied to control the errors caused in the data by noise in the communication channel. But the convolutional code does not work well with burst noise and so another process symbol interleaving will be applied when this type of noise is present.

A hardware test bed was developed to validate the analytical predictions of the convolutionally encoded and symbol interleaved TDRSS S-band return link service in a pulsed RFI environment. The test bed has three hardware subsystems: a bit generator and error rate tester, a combined convolutional encoder-decoder and an interleaver-deinterleaver. Test patterns of simulated data are passed through the system and the resulting patterns are compared with the original. Error statistics are developed and compared with the analytical predictions for the effects of the RFI phenomena on the TDRSS channels.

In this way the performance of the convolutional code and the interleaving process will be validated as realistically as possible before the TDRSS is launched.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Robert Wettingfeld
Telephone: (301) 344-7364



*Tracking and Data Relay Satellite*



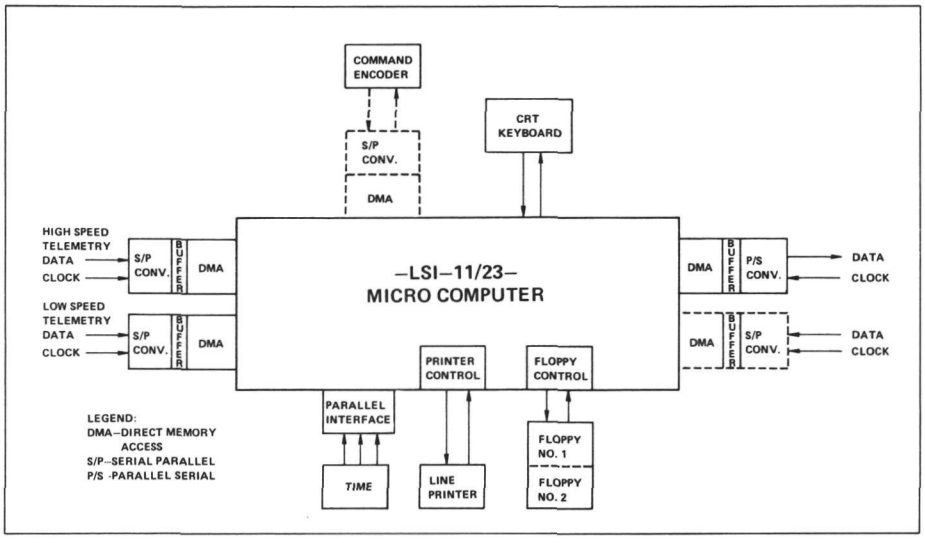
### Operations Support Computing

Initial results of the "Develo ment and Evaluation of Advanc Operations Support Computing Sy tem Designs Study," initiated th year, determined that computing tec nology will advance dramatically b the end of the decade. It is foreca that the throughput of general pu pose computers will increase by much as two orders of magnitude ar exist at a fraction of the cost of cor parable mainframes today. Because Very Large Scale Integration (VLS technology, they will require conside ably less space and power. Produ tivity will increase due to advances hardware, but software costs will co tinue to escalate because of personn costs. Of the existing and planne languages, FORTRAN appears to r main the leading candidate for scie tific applications with PASCAL Ada as likely candidates for syste programming. Subsequent to th technology forecast, system ar operation concepts were develope for a 1990's ground-based orbit cor putation system. These concep emphasize increased workload aut mation, a large product data base wi electronic interfaces for product d tribution, standardization wherev possible, and separate facilities f software development to take adva tage of the forecasted computing tec nology advances and thus increa productivity. Results of this work w provide the basis for the developme and evaluation of preliminary syste designs for a future ground-base orbit determination system.

Sponsor: Office of Space Tracki and Data Systems
Contact: Goddard Space Flight Cente
Mr. Charles McTavish
Telephone: (301) 344-8447

### ompatibility Testing of Network Isers

To assure that the Spaceflight racking and Data Network (STDN) n communicate with and adequately pport all user spacecraft, a compatiility test is run prior to launch utizing a portable tracking station lled a Compatibility Test Van TV). The function is even more itical in the Tracking and Data elay Satellite System (TDRSS) time ame. Before the TDRSS is operaonal, the CTV, which emulates the DRSS, will interface with user spaceaft at their manufacturing plant and erform the tests necessary to assure




*Compatibility Test Van Programable Data Formatter*

ompatibility with the TDRSS. Once e TDRSS is operational, the CTV ill not only retain the emulation pability for interfacing with spaceaft under development, but will so contain the capability to relay the acecraft signal via special CTV relay uipment to the TDRSS and subseently to the spacecraft control nter.

The CTV compatibility test also s the capability to perform end-to-d command and telemetry data flows between the spacecraft and its remote control center utilizing auxiliary methods of data communications. This provides the opportunity to check out control center and spacecraft software without tying up the operational TDRSS for extended periods of time.

To efficiently and reliably transfer digital data from the control center to and from the CTV, both command and telemetry data must be formatted into predefined data blocks. The formatter, which utilizes an LSI-11/23 microprocessor, is capable of formatting multiple data streams with combined data rates exceeding 1 MBps. The system accepts command blocks over the same duplex line, transfers the blocks to the command encoder for deblocking and uplinking to the spacecraft, and multiplexes the command response blocks into the telemetry data block stream.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. I. Galicinao
Telephone: (301) 344-9257

### Shuttle Digital Voice

The first Space Shuttle flew a new digital voice system replacing the analog-type systems previously used on manned flight missions.

Digital voice transmission techniques offer several advantages over analog techniques including improved voice quality, ability to multiplex voice signals and telemetry data, reduced complexity, and ease of encryption for privacy and secrecy.

To provide the necessary compatibility between the Space Shuttle and the Goddard Space Tracking Data Network (GSTDN) (prior to the availability of an operational TDRS), GSFC successfully implemented a digital voice capability into the GSTDN. The new equipments provide for the appropriate modulation and multiplexing between the Mission Control Center at the Johnson Space Center and the Space Shuttle.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Curtis Schroeder
Telephone: (301) 344-5516

### Intelligent Terminals

The Space Shuttle, the Tracking and Data Relay Satellite System (TDRSS), and the greater complexity of spacecraft will all contribute to an increase in requirements for operational orbit support in the 1980's. Faster response and greater reliability and flexibility will be the primary criteria on which computational support will be evaluated in this decade. Increasingly complex software also will accentuate the development and maintenance demands on the system.

The Intelligent Terminal research focuses on increasing productivity, quality control, and decreasing

manual intervention as well as reducing the workload on the host computer.

In support of this task, a Research and Technology Support Facility has been designed and implemented integrating intelligent terminals with a host computer. The terminals are being investigated for their capability to:

- Prepare job input streams for submittal to the host computer
- Inspect and examine task output
- Automatically schedule and execute specific recurring jobs
- Act as graphics devices for background jobs on the host computer.

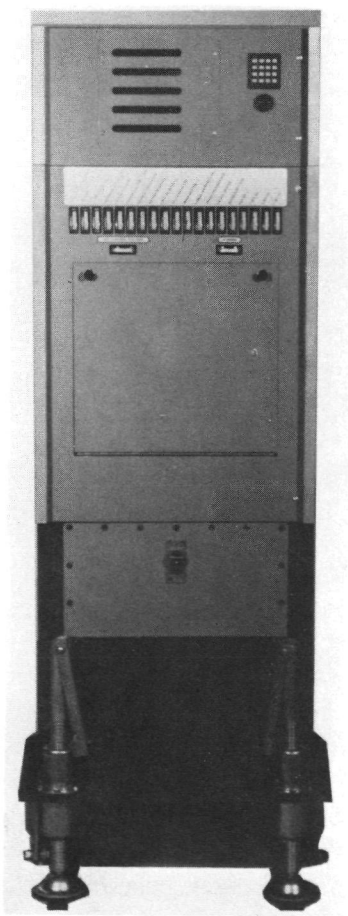
The terminals can also act as front-end processors to the host computer to screen input for validity and format. This will afford the users the capability for quick, on-line error detection and correction, even for large background tasks scheduled for later execution on the host computer.

In addition, small local programs can be run, source code entered, and routines compiled, even when the host computer is unavailable. Software development will be made simpler, faster, and more reliable by the use of intelligent terminals for local storage of developmental source code and for text-editing, and compiling source programs until they are ready to be implemented on the host computer.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Donald Ketterer
Telephone: (301) 344-6506

**Hydrogen Maser Frequency Sources**

To support NASA's programs to improve our understanding of the dynamics of the Earth's crust and to allow the ultraprecise tracking of deep space vehicles, Goddard Space Flight Center (GSFC) has an active program to develop ultrahigh precision atomic hydrogen maser clocks and to provide and support these clocks for NASA users at remote radio tracking facilities. For both crustal dynamics and deep space tracking, these clocks are used to determine the relative positions between radio beacons in space and tracking stations on the ground by measuring the differences in the arrival times of the radio signals at the tracking stations. To meet their requirements, both users require hydrogen maser clocks to keep time to trillionths of second for period of hours and billionths of a second for periods days. The GSFC's latest NR series hydrogen maser clocks have recent been shown to more than meet the requirements. Recent data show them capable of keeping time to 3 te trillionths of a second for sho periods of time, to 10 trillionths of second for periods of several hour and to better than 1 billionth of second per day. Recent field tes have also shown these clocks to pe form well in remote locations. B cause of a microprocessor-based r mote monitoring and control syste built into the clock, personnel GSFC can monitor and control th clock's performance at remote loc tions via telephone lines. With this sy tem, the clocks have been succes fully operating at remote facilitie without the presence of the traine maintenance personnel. This is leadir to considerable savings in terms operating manpower for these remo facilities.



*The newest model of the NR Series of the Maser Frequency sources in meeting the clock requirements of the Crustal Dynamics program. Two of these clocks will agree to ten trillionths of a second for several hours.*

Sponsor: Office of Space Trackir and Data Systems
Contact: Goddard Space Flight Cente Dr. Victor Reinhardt
Telephone: (301) 344-7486

## MISSION AND DATA OPERATIONS

The objective of the GSFC's work in this area is to provide the new concepts and design base required for the effective implementation and operation of near-Earth mission control and data processing systems during the 1980's. Principal related activities during the past year addressed software development, man/machine interfaces, attitude/orbit determination, computer-to-computer communications, image processing, and mission control.

### Software Development

Having completed numerous software experiments which were designed to test and evaluate approaches to the software development process, efforts recently have concentrated on the application and documentation of the results. Three associated documents include "Recommended Approach to Software Development," "Guide to Data Collection," and "The Software Engineering Laboratory." These documents will be used as the basis for continued experiments as well as the basis for standard guidelines for developing flight dynamics applications software. In addition, a localized model for software cost predicting (META-Model) is now being applied to flight dynamics projects with very favorable results. Efforts to refine the model further, as well as to evaluate its application to areas outside flight dynamics, have also been initiated.

During the upcoming year, software methodology investigations will include experiments with different software team organizational concepts such as the use of the "Product Engineer" concept where the software designers/coders are completely separated from the software implementers/testers. Such concepts have the potential for even larger cost savings than the 20 percent savings observed over the past several years.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Frank McGarry
Telephone: (301) 344-5048

### Man/Machine Interfaces

The man/machine research activity is addressing two major problem areas. The first focuses on human-engineered interface mechanisms to large complex operational systems, specifically, application and audio/touchtone technology which will support user interfaces with computing facilities for software development and testing. Within the last year, a proof-of-concept microprocessor system utilizing touchtone telephones and incorporating voice input/output has been implemented. Currently, this system is being evaluated by a pilot group of users.

A second activity addresses data/information storage/retrieval and display. The management of data, especially data which is maintained distributively, becomes complex if there is no underlying and supportive common structure. During the past year, such a common structure has been developed. The structure is embedded in a system which not only addresses the problem of access to distributed data in a standard way, but also utilizes state-of-the-art display technologies for the presentation of the data to users. The common structure is based on a novel use of a "frame" concept, and the presentation of the accessed data to the user involves the so-called "cluttered desk" approach. This display technique allows the user to display and work with several data frames simultaneously allowing for a broader view of the dynamics of the system with which he is interfacing. Currently, the system is experimental. During the next year, the associated technology will begin to be transferred into several operational environments at the GSFC for further demonstration and evaluation.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Walter F. Truszkowski
Telephone: (301) 344-6222

### Attitude/Orbit Technology

Orbit and attitude computations have traditionally been performed on large, main frame computers primarily due to the large data bases and the complex models required in the computations. Recent advances in microelectronics hardware have opened the door to performing these computations in distributed mini and microcomputers which may be on board the spacecraft or at distributed locations on the ground.

To take advantage of these hardware technology breakthroughs, the GSFC engineers are developing data processing techniques and breadboard orbit and attitude systems which may be placed on board the satellites or at distributed ground locations such as the control centers. During 1981 a preliminary design of an on-board automated orbit determination system using the Tracking and Data Relay Satellite System (TDRSS) data was completed. Based upon this design, the capability for performing on-board orbit determination with the TDRSS data will be incorporated into a new digital transponder.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Arthur J. Fuchs
Telephone: (301) 344-6846

### Image Processing

In an effort to meet the future needs of important segments of the remote sensing user community, NASA is developing new sensors with increased spectral, radiometric, and spatial resolution. By the late 1980's or early 1990's, sensors of the Multispectral Linear Array (MLA) type may produce $10^{10}$ or more bits per Landsat size (185km x 185km) scene. Approximately fifteen 2400-foot reels of standard 1/2-inch wide computer tape recorded at 6250 bpi would be required to store a single scene containing this much data. Thus, for small users, processing even a single scene on a standard computer system would be a difficult and unweidly process.

In order to provide a solution for this problem, NASA is supporting the development of computer-compatible digital optical disk recorder/reproducers. These devices use laser light to record more than $10^{10}$ bits of data on a single surface of a 12-inch plastic disk coated with a thin layer of optically sensitive material. Cost projections indicate that read-only digital optical disk units will be similar in cost to standard computer magnetic tape units and that the cost of unrecorded disks may fall to as low as $10.

NASA is currently negotiating a contract to develop a detailed systems design for a prototype computer-compatible optical disk system optimized for use in an image processing environment. A complete prototype optical disk data storage system is expected to be in place at NASA's GSFC by 1984.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Fred McCaleb
Telephone: (301) 344-5470

### Computer-to-Computer Communications

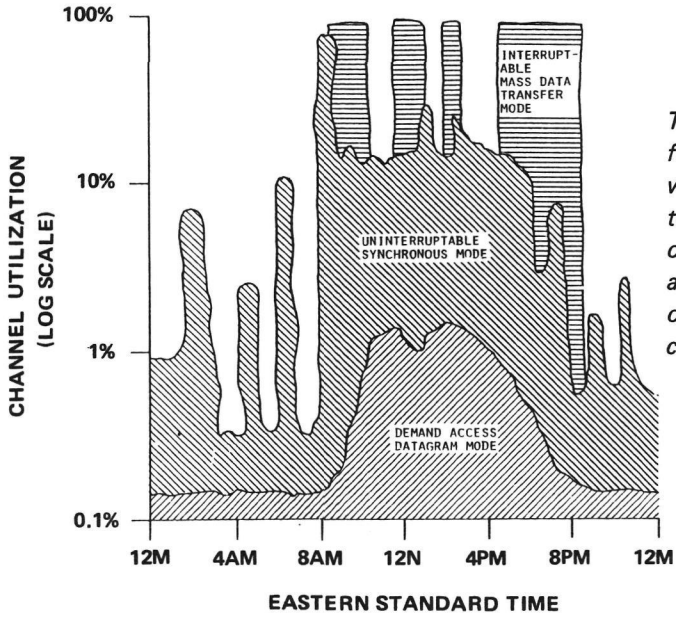
Communication satellites can provide a cost-effective alternative to ground-based telecommunications circuits needed for NASA mission operations. Unlike the ground-based circuits, the communications bandwidth through satellite transponders can easily be assigned among the communications nodes on the basis of current need. However, to provide this coordination communications protocols must be developed which permit users to request, utilize, and release the communication bandwidth resources. In analyzing the NASA mission operations communication requirements, three classes of services were identified:

- short transaction-oriented messages (commonly referred to as datagrams) which must be quickly delivered to the destination;
- real-time telemetry messages for which a guaranteed fixed bandwidth capability must be assigned for a predetermined duration; and
- mass file transfers in which files of data must be delivered to destinations within a given interval; however, the instantaneous data transmission rate may be varied to accommodate the needs of the other two classes.

A compatible set of communication protocols were developed to permit these three classes of messages to efficiently share the available satellite transponder bandwidth. Future activities will focus on the development of low-cost Time Division Multiple Access (TDMA) stations to transmit and receive messages via a communication satellite in broadcast mode.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Mr. Edward P. Greene
Telephone: (301) 344-8685

**Typical Hypothesized Traffic Loading**




*Typical Hypothesized Traffic Loading. Recently developed demand access protocals can handle mixtures of message traffic with a combined data volume of up to 99% of available channel capacity.*

## ssion Control

The Multisatellite Operations Con-
ol Center-I (MSOCC-I) at the GSFC,
the control center facility for many
ar-Earth flight programs, includes
veral computer systems which must
rapidly reconfigured when going
om support of one spacecraft to
other spacecraft. The present
ethod of reconfiguration is via
anual switching by the Data Opera-
ns Controllers. The manual
itches are being replaced by com-
ters which are collectively called
ta Operations Control System
OCS). The DOCS will provide auto-
ated control of system configura-
ns, automated loading of computer
ftware, and operational flexibility in
idly configuring available re-
urces. The automated DOCS will
o assure more reliable and repeat-
le configurations and will increase
e capability to troubleshoot system
oblems.

During the past year, related re-
arch activities have been directed
ward defining the interfaces to the
OCS, determining the benefits and
ks of automation, and the develop-
nt of the operational requirements
the DOCS system. Resultant per-
rmance gains will allow the support
up to 15 missions (any 6 simul-
neously) with less manpower, more
iciency, and greater reliability than
rrent systems.

onsor: Office of Space Tracking
and Data Systems
ntact: Goddard Space Flight Center
Mr. Roger V. Tetrick
ephone: (301) 344-7202

*Automated reconfiguration of mission control facilities through a data operations control system can significantly improve Goddard's capability to handle a wide range of spacecraft.*

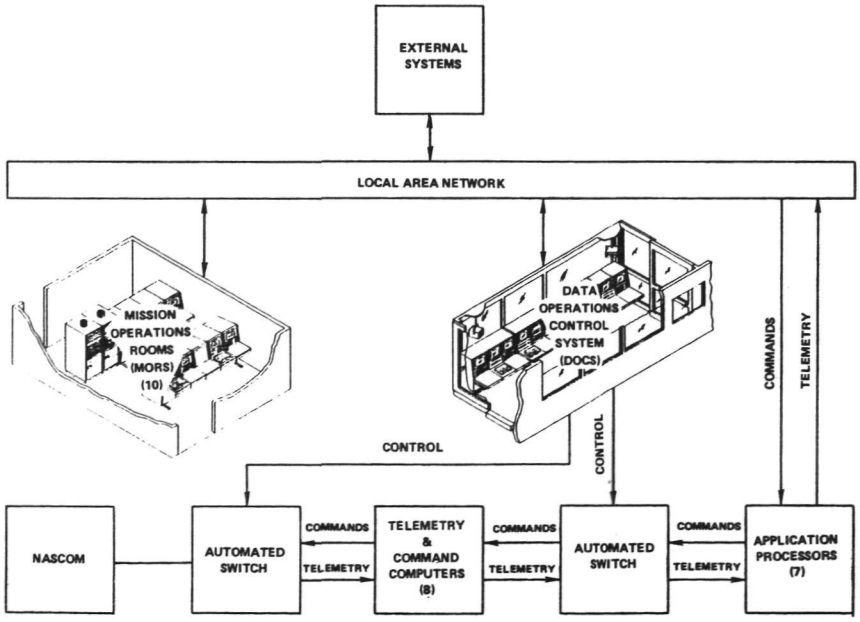
## NASA Laser Tracking Network

A network of laser tracking stations, strategically located throughout the world is managed by the Goddard Laser Tracking Network Project Office. The Goddard Laser Tracking Network (GLTN) consists of both fixed and mobile laser tracking systems used for precision satellite tracking to provide precise geodetic measurements. The mobile systems are deployed and operated at various locations around the world in response to program requirements. The composition of the GLTN will vary throughout the decade. Initially, the network will consist of seven mobile laser systems (Moblas 2, 3, 4, 5, 6, 7, and 8); three transportable laser ranging systems (TLRS-2, 3, and 4); and two fixed laser ranging stations (SAO-2 and 4) located at Arequipa, Peru, and Orroral Valley, Australia, respectively.

The first set of mobile laser stations (Moblas 1 to 3) were equipped with high-energy, cavity-dumped ruby laser transmitters built by Korad. The second set of stations (Moblas 4 to 8) were equipped with Q-switched Nd:YAG laser transmitters built by General Photonics having a FWHM pulsewidth of about 7 nanoseconds. Current Moblas receivers are designed to detect and process laser pulses of about 5 nanoseconds duration. In the field, these stations typically achieve ranging accuracy on the order of 8 to 12 centimeters and a serious effort is currently underway to upgrade the performance of these stations, using the best available commercial components, in order to meet the scientific requirements of the next decade.

In order to minimize the interruption of data from the stations during the upgrade period, all engineering modifications (hardware and software) will be implemented and verified on Moblas 4 prior to its adoption by the entire Moblas network. Modification and upgrade of Moblas 4 is being carried out in stages at the Goddard Space Flight Center and began with the installation of a passively modelocked Nd:YAG laser transmitter in late July 1981. As of September 1981 the system has successfully tracked three satellites--Lageos, BEC, and Starlette with ranging accuracy on the order of 2 to 3 centimeters.

The passive transmitter, which is considerably less expensive than a comparable actively modelocked laser due to its relative simplicity, has



proven reliable in the field, and it is anticipated that similar lasers will be installed in Moblas 5 through 8 by spring 1983.

Several modifications to the Moblas 4 receiver are also in progress. In November 1981, the Moblas 4 configuration will be frozen. The system will then undergo collocation testing with Moblas 7 which is equipped with an actively-modelocked Sylvania laser.

Following completion of collocation tests with Moblas 7 in mid-December, the Moblas 4 ranging subsystem will be installed in Moblas 8 and will participate in the 1982 measurement campaign in Southern California. Since the Moblas 4 ranging system detects multiple photoelectrons, it will provide a valuable comparison to other subnanosecond pulse systems, such as TLRS-1 and TLRS-2, which use single photoelectron detection schemes.

Sponsor: Office of Space Tracking and Data Systems
Contact: Goddard Space Flight Center
Dr. Andrew Adelman
Telephone: (301) 344-7338

## ENGINEERING

GSFC engineers have been working on a variety of tasks that use advanced technologies to develop new and improved methods for handling data.

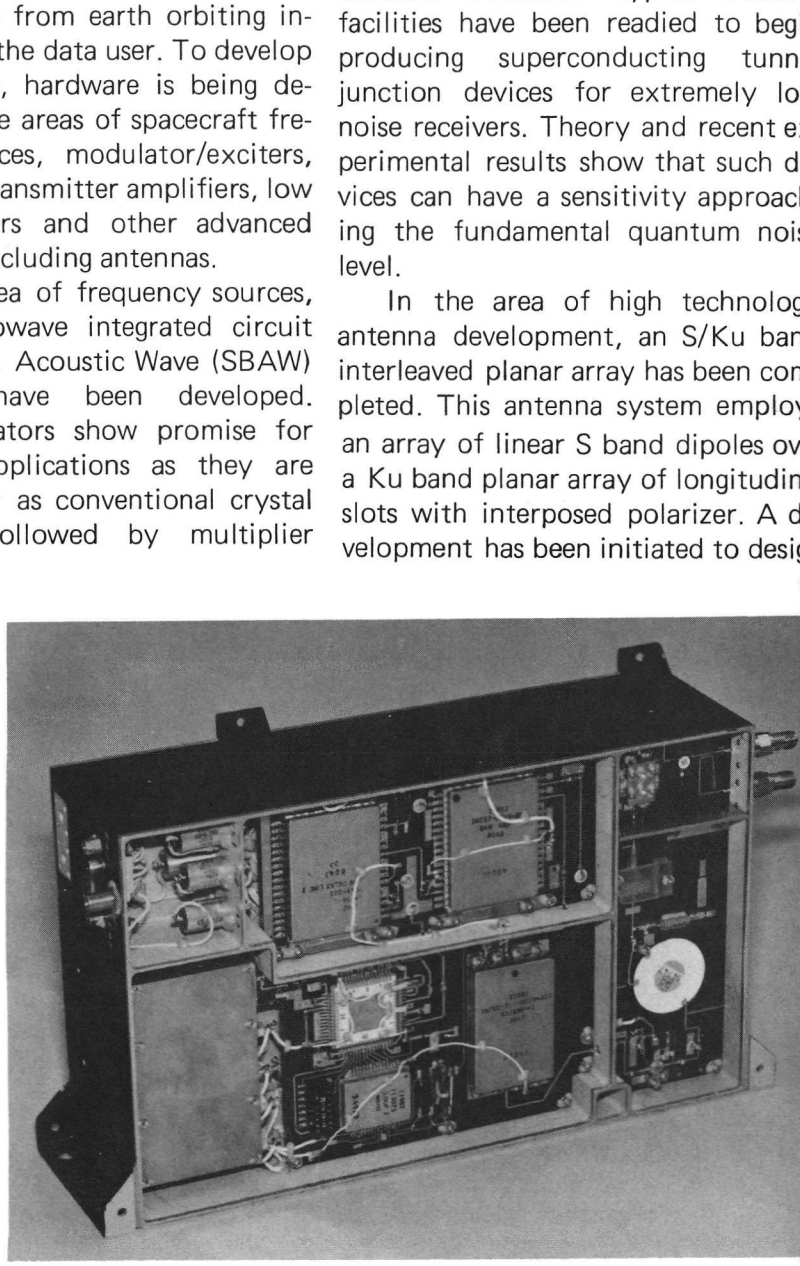
### High Speed Data Transfer

Technology is being developed that will result in space communication systems capable of transferring data at rates of thousands of megabits (gigabits) per second. Such systems will be necessary to relay large quantities of data from earth orbiting instruments to the data user. To develop such systems, hardware is being developed in the areas of spacecraft frequency sources, modulator/exciters, high power transmitter amplifiers, low noise receivers and other advanced subsystems including antennas.

In the area of frequency sources, hybrid microwave integrated circuit Shallow Bulk Acoustic Wave (SBAW) oscillators have been developed. SBAW oscillators show promise for spacecraft applications as they are not as bulky as conventional crystal oscillators followed by multiplier chains.

Low noise, wide band receive
have been developed for operation
15 GHz using Gallium Arsenide fie
effect transistors. This technology h
been extended to 30 GHz where lo
noise breadboard receivers have al
been developed. At 60 GHz, whe
field effect transistors exhibit po
performance, an integrated receiv
using an image enhanced mixer
being developed. This receiver w
use an Indium Phosphide Gunn loc
oscillator which should exhibit bett
noise performance than convention
Gallium Arsenide types. Finall
facilities have been readied to beg
producing superconducting tunn
junction devices for extremely lo
noise receivers. Theory and recent e
perimental results show that such d
vices can have a sensitivity approac
ing the fundamental quantum noi
level.

In the area of high technolog
antenna development, an S/Ku ban
interleaved planar array has been co
pleted. This antenna system emplo
an array of linear S band dipoles ov
a Ku band planar array of longitudin
slots with interposed polarizer. A d
velopment has been initiated to desi



*The High Speed Data Transfer Unit developed at the Goddard Space Flight Center is capable of transferring data at rates of thousands of megabits (gigabits) per second.*

enna arrays using dielectric horns. h antennas should be small in sical size and also less expensive to icate than those made of conven- al horn materials.

nsor: Office of Aeronautics and Space Technology
tact: Goddard Space Flight Center Mr. John Chitwood
ephone: (301) 344-6375

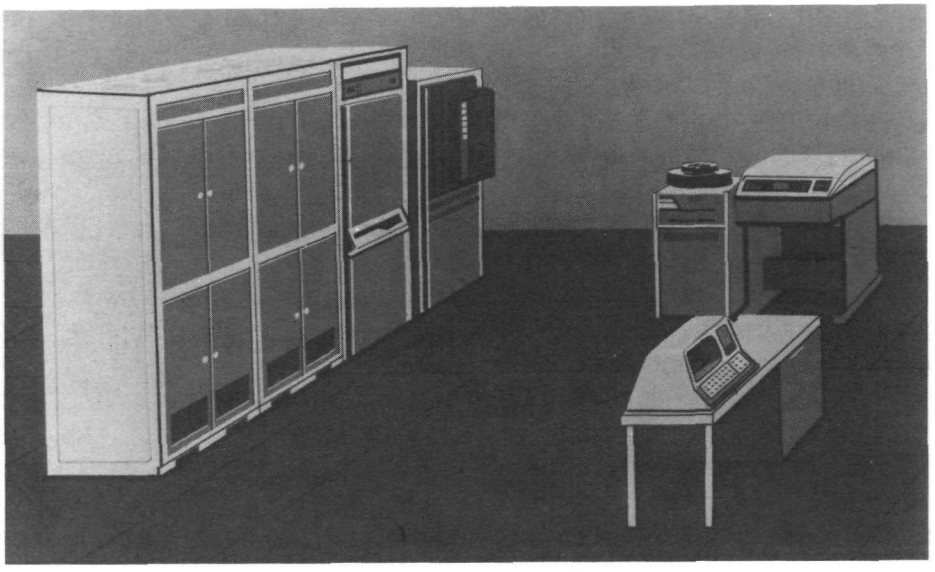
### dular Data Transport Systems

Advanced data transport and und handling concepts were veri- , and implementation approaches e tested and evaluated during 81. They utilized on-line demon- tions of a system containing the or functional elements of an rational packet telemetry data ing system. The data staging sys- is that portion of the end-to-end a system which lies between the und data acquisition station and a users' processing system. Func- s demonstrated include telemetry ne synchronization, instrument a packet reassembly, user data set eration, data accounting, data lity annotation, and store and vard service. The demonstration em is oriented toward realizing potential advantages in automated ration (lower cost) and reduced a delivery times (higher perfor- ce) provided by packet telemetry. results are being utilized in the gn of operational systems for up- ing missions such as the Space scope, Gamma Ray Observatory, other potential users.

nsor: Office of Aeronautics and Space Technology
tact: Goddard Space Flight Center Mr. Richard Carper
phone: (301) 344-6414

### Massively Parallel Processor

The Massively Parallel Processor (MPP) is a special purpose computer with an architecture consisting of an array of 16,384 processing elements. The MPP is designed for rapid and economical extraction of information from data, especially data in the form of an image. The MPP's six billion operation per second rate for 8 bit integer arithmetic and 200 million 32 bit floating point operations make MPP usable in a wide variety of computational problems.



*The Massively Parallel Processor System which is used for demonstrations and research for the government and industry.*

The MPP includes a large multi-dimensional access memory which serves as a rate buffer, a scratch pad for the array, and data permutations.

The MPP system is a demonstration and research system for government, academic and industry use to verify new applications and algorithmic approaches to large scale parallel computing.

Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center Mr. Ken Wallgren
Telephone: (301) 344-5184

### Centimeter Accuracy Laser Ranging System

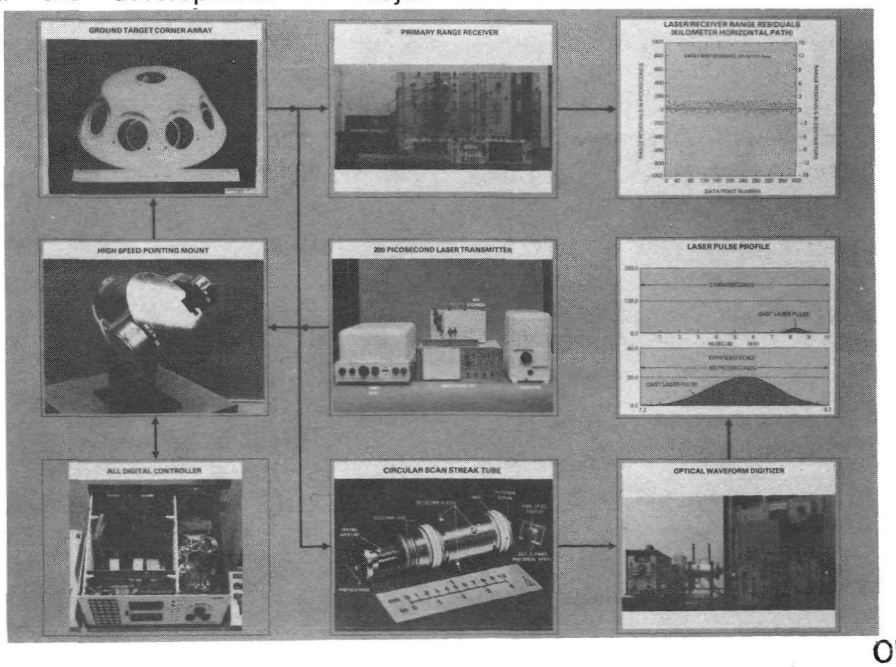
Researchers at GSFC have developed a number of advanced laser ranging components for future use in airborne and spaceborne surveying instruments. These components permit the measurement of distance to ground-based reflectors with centimeter accuracies.

One such component is a compact laser transmitter which emits a pulse roughly 200 picoseconds in duration. (A picosecond is one trillionth of a second). Taking into account the speed of light (300 million meters/sec), this corresponds to a pulse only six centimeters long. The time-of-flight of the light pulse is measured by a ranging receiver with a resolution of about 50 picoseconds. The light is directed to the ground reflectors by a precision, high speed, pointing system.

The technology developed under this program is currently being used to upgrade an existing ground-based laser ranging network maintained by GSFC. By ranging to the artificial satellite LAGEOS, this network gathers valuable scientific information on movements in the earth's crust (which can signal the development of major earthquakes), subtle motions of the earth in its orbit, and the earth's gravitational field. Current plans include the development, by 1984, of an aircraft-based system which will permit large scale geodetic and engineering surveys to be performed rapidly with improved accuracies and at a greatly reduced cost. Areas as large as 200 km by 200 km could be surveyed with centimeter accuracies in only six hours.

Besides general surveying applications, the instrument could be used to monitor: (1) tectonic plate motion and deformation on a required scale; (2) crustal deformation caused by the withdrawal of natural resources such as oil, gas, and water; (3) crustal movements affecting the stability or integrity of nuclear power plant and waste deposit sites, dams, water canals, and pipelines; and (4) the activity of volcanoes. Ultimately, a spaceborne instrument would provide a global surveying capability.

Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Dr. John J. Degnan
Telephone: (301) 344-7714




*Network diagram of the Centimenter Accuracy Laser Ranging System.*

### Spacecraft Data Systems Technology

Longer-term research has bee initiated in FY81 for the developmer of high-speed logic devices and a wid band communications bus to inte connect the high-speed elements of spacecraft data handling systen Gallium Arsenide technology offe the promise of very-high-speed con puting and data handling elements reasonable power levels such that th onboard processing of 10 to 10 megabit data streams will become fe sible. An important supporting el ment to these high-speed devices is communications bus which can deliv data to the various processors an carry processed data to the storage transmission terminals. The data bu under development utilizes fib optics for bandwidth and a new acce protocol which optimizes bandwidt utilization. The protocol allows terminals to use time on the bus r linquished by other terminals whi guaranteeing equal access to all te minals desiring service.

Sponsor: Office of Aeronautics ar Space Technology
Contact: Goddard Space Flight Cente Mr. Raymond Hartenstein
Telephone: (301) 344-5659

## Long-Lifetime Cryogenic Refrigerator

GSFC is developing a closed cycle Stirling cryogenic refrigerator to operate for 3-5 years in space. The machine, which was designed and fabricated by Philips Laboratory, will provide 5 watts of refrigeration at a temperature of -208°C.

Refrigeration is produced in a Stirling cycle by compressing and expanding helium gas in the enclosed refrigerator housing. Two moving members, called the piston and displacer, are oscillated to provide the necessary gas compression and expansion.

To achieve the extremely long lifetime and high reliability, unique design features must be employed. These include the utilization of magnetic bearings, clearance seals and linear motors. The magnetic bearings suspend the piston and displacer in a magnetic field and thus prevent rubbing, and subsequent wear, between the moving members and the stationary cylindrical walls. A small clearance between the walls and moving members acts as a seal, although some gas blowby occurs. The linear motors allow the piston and displacer to be driven directly without using bearings or a mechanism. Thus, the refrigerator requires no lubrication and should have no mechanical wear.

To date, component-level testing has been completed and subassembly testing of the engineering model unit is underway. The tests show that the linear magnetic bearings and piston motor operate as anticipated.

Commercial applications of this advancement include the possibility of wearless compressors or other machinery of this nature.

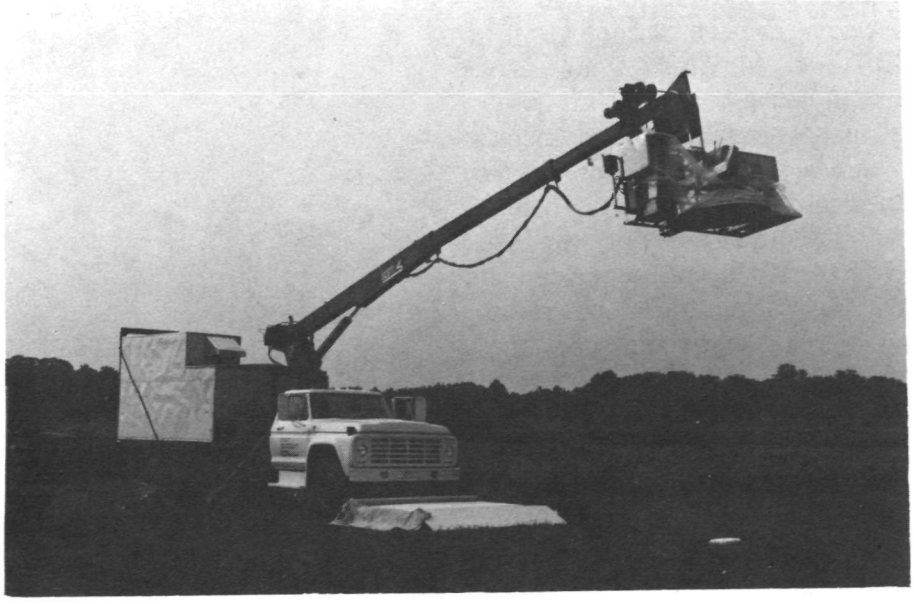
Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Dr. A. Sherman
Telephone: (301) 344-5405

## Soil Moisture Sensing Systems

GSFC scientists and engineers have been developing technology for a large space radiometer system for mapping ground soil moisture content. Because of high sensitivity to soil moisture variation at frequencies < 3 GHz, which are desirable in agricultural, hydrological, as well as meteorological applications, space antennas in the 10 to 100 meter range are required in order to achieve spatial resolutions of approximately 1 to 10 km.

Radiometric response to soil moisture variation is based on the principle that water makes soils less emissive. A soil's thermal microwave emission, as measured in terms of brightness temperature by a radiometer, depends on its water content. Results from field experiments conducted jointly by GSFC and the Department of Agriculture personnel in the past few years reveal that a soil's brightness temperature can vary from approximately 180°K to approximately 280°K as it changes from wet to dry conditions. These experiments are made with microwave radiometers in the frequency range of 0.6 GHz to 10.6 GHz, mounted in a mobile tower. The major objective of these efforts is to understand quantitatively the effects of soil water content, soil type, and vegetation cover on the radiometric outputs. This will then help us develop the technique of inverting brightness temperature obtained by a spaceborne radiometer system into ground soil moisture content. Although a microwave radiometer at a frequency < 3 GHz has poorer resolution compared to other Landsat and Nimbus sensors in the visible or infrared region, the high sensitivity to soil moisture variation and the ability to penetrate through moderate cloud cover make the microwave radiometer an attractive, all-weather soil moisture remote sensor. These channels below 3 GHz also have the ability to penetrate moderate vegetation making the measurement of soil moisture possible during the complete growing cycle.

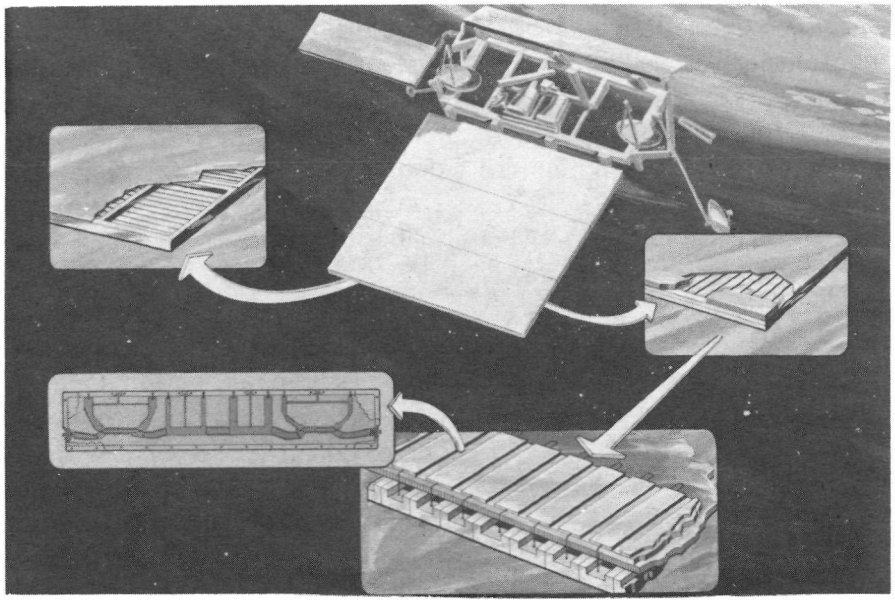
The tradeoff among orbital altitude, swath width, scan geometry, and antenna type is a complex question under investigation at GSFC. Studies have shown that a 1.4 GHz radiometer with 10 km resolution and 800 km



*Soil Moisture Field Measurements made with microwave radiomenters.*

swath width can map soil moisture over 80% of the U.S. agricultural regions and provide a 3-day coverage. These criteria have been used as sensor design drivers for a future spaceborne radiometer system. Both reflectors and phased arrays are being studied to meet these requirements.





*Satellite with 10x10M, 1.4GHz microwave Radiometer--Parts of waveguide array shown.*

Reflector systems which offer multifrequency operation, not possible in simple arrays, are also being studied. These reflector structures must be mechanically scanned to form about one hundred simultaneous beams to achieve an 800 km swath. GSFC is now studying the mechanical scan approach, but the feasibility of mechanically scanning these 15 to 20 meter reflectors has not yet been shown. Antenna performance and NASTRAN structural models now being developed should give these answers next year.

Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Mr. J. L. King
Dr. J. Wang
Telephone: (301) 344-8949
(301) 344-9112

# VI Space Technology

*The Space Technology Program at GSFC is directed toward providing advanced technology for handling data from future space missions and for making maximum use of space technology for the benefit of mankind. Programs have been focussing on long range requirements in data systems technology and new technology developments.*

## DATA SYSTEMS

Several projects were undertaken in Fiscal Year 1981 in developing technology for advanced data systems to improve NASA's data handling capabilities in future flight missions.

### NASA End-to-End Data System (NEEDS)

The NEEDS technology program led by the GSFC represents a major activity in data systems which was initiated in Fiscal Year 1979 (FY79). The broad objectives of the NEEDS Program are to develop and demonstrate advanced spacecraft and ground data system technologies and techniques which will facilitate the implementation of an end-to-end data system with significant improvement in systems performance and cost-effectiveness.

In FY81, the NEEDS Program completed designs for prototype systems which perform on-board spacecraft image preprocessing and editing, creation of on-board autonomous data modules, and ground management, processing, and archiving of high-rate data. Demonstrations of these prototypes will be performed in late FY82 and early FY83 and will show the potential for significant improvement in NASA data system performance.

Sponsor: NASA Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Mr. Robert Nelson
Telephone: (301) 344-7809

### Resource-Effective Data System (REDS) Study

In addition to the technology development aspects, the NEEDS Program has studied the cost/performance impact of alternative data management systems through modeling and simulation. A model has been constructed of an end-to-end data system which includes a spacecraft, tracking and data acquisition, data staging and processing, and users' interaction. An important feature of this model is its ability to dynamically interrogate multiplexed data streams and perform switching based on the sampled rate. This allows for real-time buffer configuration and network simulation. Further, the model provides statistics on lost data due to excessive rates, buffer overflow, and other real-world criteria. Due to the model's computerized interactive graphics capability, the modeler can observe selected queues and utilization statistics as the simulation progresses and can generate comparative case studies by simply changing one or more input parameters.

Sponsor: NASA Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Mr. Thomas Grenchik
Telephone: (301) 344-6373

### Automated Decisionmaking

Under normal operations, NASA data management for near-Earth spacecraft involves user requests for spacecraft activity; command generation and verification; scheduling of spacecraft service links; orbital computations; attitude determination; and data and image processing including attaching the ancillary orbit, attitude, and time data. Activity in the present system is a series of discrete, sometimes asynchronous, discontinuous events wherein sizeable procedural delays mask the irregularity of data and communication flows. The advent of planned system enhancements such as Tracking and Data Relay Satellite System (TDRSS), the upgrading of the operations control centers, and the new Network Control Center (NCC) coupled with the potential impact of such proposed enhancements as packetization, on-board computation of ancillary data, and on-board data editing will have the effect of producing a more continuous activity stream and data flow. This will require expert scheduling of activities and allocation of resources to realize efficient use of the system.

A study was initiated in 1980 to examine how deterministic techniques, operations research, and artificial intelligence approaches might be brought to bear on scheduling and allocation within individual functions as well as on a system-wide basis. In FY81 the general characteristics of a resource allocation and event scheduler were defined and a pilot system built. Demonstration of this pilot in the Multisatellite Operations Control Center (MSOCC) was so successful that, with very slight modifications, it will be adopted as an operational tool in MSOCC, thereby eliminating the tedious, time-consuming manual scheduling now used.

Sponsor: NASA Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Center
Mr. Jesse L. Maury
Telephone: (301) 344-5149

## TECHNOLOGY UTILIZATION

During the past years, GSFC has been directly involved in NASA's Technology Utilization Program which is applying space developed technology to benefit mankind on Earth.

### Energy Efficient Fan Control

A new invention developed by a Goddard engineer could cut costs of power supply for heating and air conditioning and reduce currently required horsepower in operating variable volume system fans by 50 percent or more.

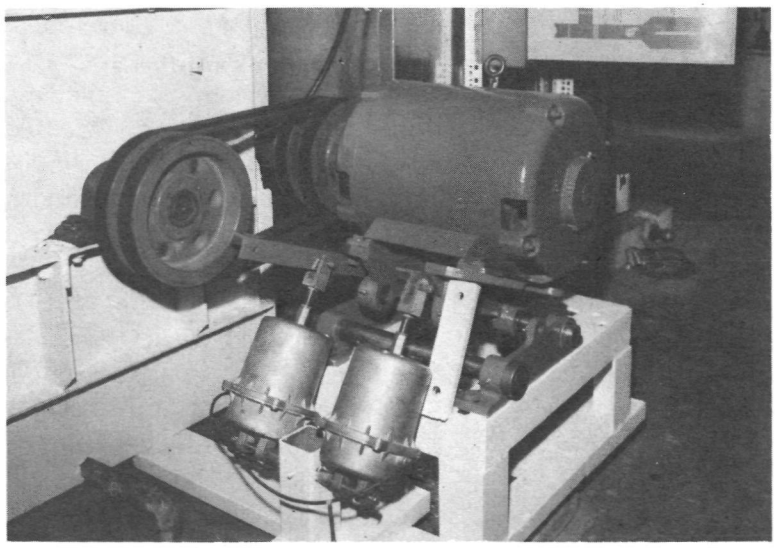
Many methods of varying speeds have been developed and Mr. Henry Obler's new invention differs only in its simplicity and its lower cost. Previous means of varying motor speeds are complex, costly, and difficult to accomplish. Therefore, the Goddard-developed drive provides a low-cost method of varying fan speed automatically in response to a static pressure signal and can also provide a lo cost method of varying pump spe automatically in response to a wa pressure signal. As the fans' a pumps' speed is reduced, the curre draw and the power of the motor reduced considerably, resulting energy savings.

The motor in Obler's new inve tion can be mounted on a standa sliding-type motor base where the dri screw and the handle have been moved. One of the sliding bars is moved from the base, and allows t portion of the base supporting t motor to swing around the remaini gliding bar.

Another advantage of the arc-li motion of the mechanism is its ve low friction which therefore requir little force to move the motor forci the pulleys open.

For years, variable air volume sy tems have promised much in ener savings and in cost effectiveness. No its users can look forward to cutti costs and saving energy at the sar time.

Sponsor: Office of Aeronautics and Space Technology
Contact: Goddard Space Flight Cent
Mr. Henry Obler
Telephone: (301) 344-7728



*Energy Efficient Fan developed by a GSFC engineer.*